2004 OSCC/WTFRC
Cherry/Soft Fruit Research Review
November 6, 2003
Pasco, Washington

Time	Pg	Name	Title	Duration
8:35	6	Núñez-Elisea	Cultivars, rootstocks, training systems, and fruit quality	03-05
9:20	12	Núñez-Elisea	Tree water use, irrigation scheduling, and water management	03-05
6:45	17	Whiting	Clonal rootstock evaluation	04-06
9:35	21	Whiting	Alternative water management strategies	02-04
10:25	25	Whiting	Intensive sweet cherry orchard management	01-03
9:05	30	Azarenko	Horticulture management systems	90
9:45	49	Schrader	Suppressing cherry cracking, stem browning, and water loss	03-04
8:50	59	Núñez-Elisea	Chemical bloom thinning	01-03
10:10	62	Whiting	Quantifying limitations to balanced cropping	01-03
10:40	66	Elfving	Bioregulators for growth, precocity, and mechanical harvest	01-03
9:40	71	Elfving	Induction of branches in sweet cherry trees	02-04
10:55	78	Grove	Epidemiology and control of powdery mildew	01-03
2:30	84	Eastwell	Protecting PNW orchards from virus threats	01-03
1:40	89	Yee	Host and feeding preference of cherry fruit fly	01-03
1:50	95	Yee	Cherry fruit fly distribution and trapping	02-03
1:30	101	Yee	Factors affecting mating in cherry fruit fly	01-03
3:15	113	Peterson	Mechanical harvester for stemless cherry	03-04
7:00	125	Iezzoni	Sweet cherry dwarfing rootstocks	CVRC

FINAL REPORT
WTFRC Project #CH-01-05 Agricultural Research Foundation #3740

Project Title: Propagation and production of tree fruits and nuts

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Objectives: Overall, this project conducts research on similar propagation problems of cherry, pear and hazelnut to: 1) help the flow of new germplasm through research towards commercial propagation, 2) improve propagation of these species by cuttings and tissue culture and 3) maintain several dozen clones of these crops in the field and in tissue culture.

Significant Findings:
Over the past three years:
1) Commercial propagation of the Gisela series of clonal cherry rootstocks by micropropagation and softwood cuttings has become routine.
2) We have facilitated the movement of PiKu and Bz series of clones from overseas into research trials as part of the Germplasm Research Consortium.
3) Improved micropropagation of cherry by the use of double-phase tissue culture and other techniques.
4) Developed a system to regenerate genetically transformed cherry rootstocks.

Methods:
Cuttings. Cuttings comprised the sub-apical 10" of vigorous shoots that were still actively growing in late June and early July in Corvallis. The leaves were removed from the base of the cutting which was treated with 15 mM (2800 ppm) IBA in 50% ethanol and water.

In our greenhouse facility, mist was applied at variable intervals: 0700 to 0900 hours, 24 min interval; 0900 to 1000 hours, 16 min interval; 1000 to 1700 hours, 8 min interval; 1700 to 1900 hours, 16 min interval; and 1900 to 2000 hours, 24 min interval, with 8 second duration at each misting. The propagation medium is typically perlite:peat (3:1) in 2 1/4" x 5" bands. Flats containing bands were placed in 4' x 17' benches enclosed on all sides by clear poly extending about 3' above the bench. Temperature of the medium ranged from 70^{o} to 80^{o}F. Maximum air temperature was 85^{o}F.

Micropropagation. Cherry clones were established in sterile conditions by surface sterilizing actively growing shoots in 10% bleach solution and planting the shoots on MS medium consisting of 0.8% agar, 3% sucrose plus MS salts and vitamins. Shoots which were sterile and still actively growing were transferred to a multiplication medium consisting of DKW medium plus 1 ppm benzylaminopurine (BAP). Every 4-6 weeks, shoot clumps were divided into single shoots and re-cultured on multiplication medium.

When liquid medium is used in double-phase culture, enough liquid is added, about 25 ml, to nearly cover shoots that had just been divided and transferred.

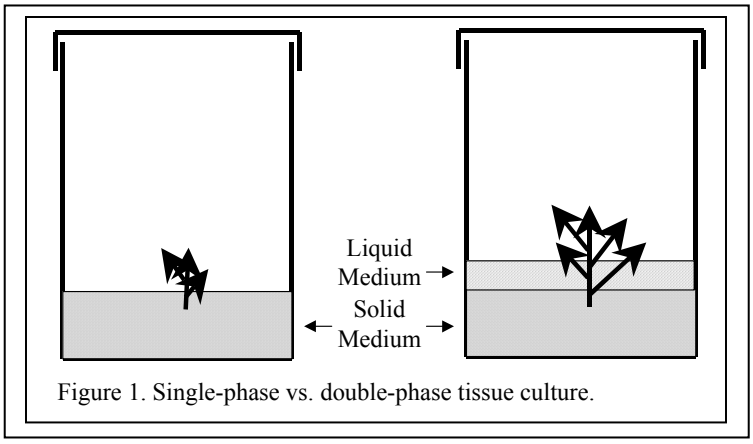


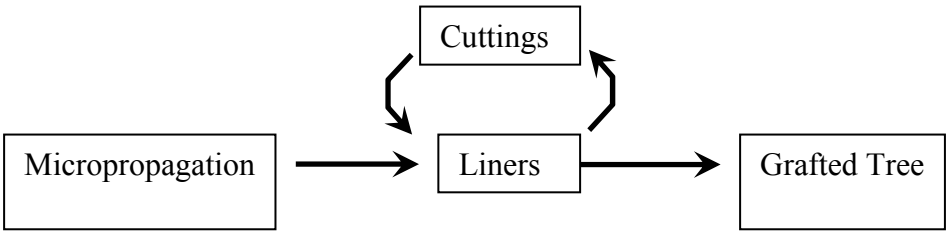
Figure 1. Single-phase vs. double-phase tissue culture.

When a sufficient number of shoots are available, the surplus is treated with indolebutyric acid (IBA) to stimulate rooting. Rooted shoots are transplanted into clean potting medium, grown under intermittent mist for two weeks and then transferred to the greenhouse. In the greenhouse, the shoots are grown to liner size and transferred to other research programs.

For transfer to commercial micropropagators, shoot cultures are sealed in sterile, plastic pouches containing a small amount of DKW solid medium and mailed to the nursery.

Transformation. Agrobacterium strains carrying genes for antibiotic or herbicide selection and GUS reporter genes are used to inoculate cherry leaves at the time they are cut and placed on Regeneration Medium 1 (RM1). After three days, the shoots are washed and placed on fresh RM1 containing plant growth regulators thidiazuron (10 □M) and α-naphthaleneacetic acid (1.25 □M) and antibiotics, Timentin, 400 mg/l and Cefotaxime, 200 mg/l (which kills the bacteria) and usually Kanamycin, 25 mg/l (which kills the untransformed plant cells). Leaves are then transferred to RM2 containing plant growth regulators benzylaminopurine (5 □M) and α-naphthaleneacetic acid (0.5 □M) along with the same antibiotic selection as above. Callus is grown from transformed cells and then used for shoot regeneration.

Results and Discussion:



Cuttings. When this project began, the Gisela clones were micropropagated on a limited basis. Softwood cuttings, an economical alternative, were not considered feasible. The system that we developed depends on micropropagated stockplants which produce cuttings of high rooting potential. The simple techniques described in the methods section can be used in even rudimentary mist systems in simple glass or plastic structures to produce high percentages of well-rooted cuttings. Production of softwood cuttings went from zero to roughly 250,000 cuttings per year. Most of them are derived from the production scheme illustrated above.

Micropropagation. The Gisela clones micropropagate fairly readily, however, the Piku and Bz clones initially grew very slowly in tissue culture. Double-phase culture improves micropropagation of all clones, and makes micropropagation of the PiKu group possible (Table 1). Without double-phase, these clones die out in culture, with double-phase all but 4.13 produce reasonable multiplication rates. The importance of double-phase is also illustrated in Figure 2. Double-phase increases multiplication rate, but growth declines in subsequent, single-phase transfers.

Table 1. Multiplication rates of PiKu and Bz clones.

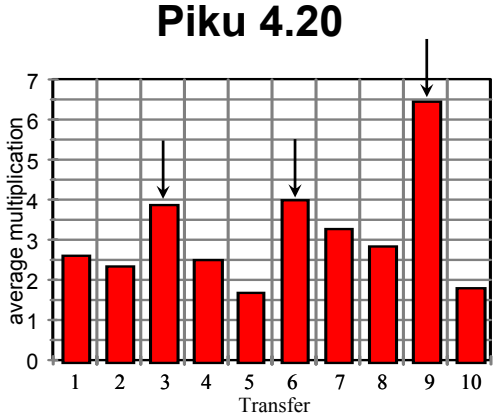
	Multiplication Rate	
Clone	Single Phase	Double Phase
PiKu 1.10	1.2	4.1
PiKu 4.11	0.9	1.8
PiKu 4.13	-	0.7
PiKu 4.17	1.0	2.4
PiKu 4.20	0.9	3.1
PiKu 4.22	1.3	3.5
Bz-3-II	0.7	4.7

PiKu 4.13 has continued to be difficult to micropropagate, however. In spring, 2002, we initiated over 30 rapidly growing shoots in tissue culture and used double-phase culture as soon as the shoots were confirmed to be sterile. However, the multiplication rate continues to decline in subsequent transfers to fresh double-phase medium.

Testing Germplasm. Using these micropropagation techniques, as well as methods for propagating softwood cuttings that have been described in previous reports, we help the flow of new rootstocks through the research system and into commercial propagation. The major focus is to feed liners to the Germplasm Research Consortium (GRC). About 200 Gi6 are provided annually for scion testing. We also provide material for other research programs. Two hundred plus liners of the PiKu and Bz clones were sent to Prosser in spring, 2002, for field testing by the GRC. If these clones have promising production potential, cultures will be transferred to commercial micropropagators.

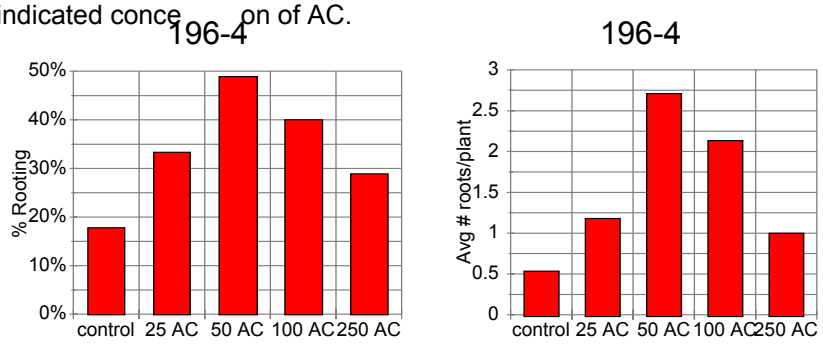
In Oregon, Anita Azarenko is particularly interested in Gi 196-4 for the Willamette Valley. We provide about 200 liners per year for her studies. We have provided tissue cultures and assistance to help Greg Lang develop his program at Michigan State. Several of the Giessen clones are hypersensitive to Prunus Necrotic Ringspot Virus (PNRSV). We provide liners of some of these clones for Bill Howell's work at Prosser. Each year, Jack Pinkerton, a USDA scientist at Corvallis, uses cherry liners for nematode studies.

Fig. 2. Effect of double-phase (arrows) on multiplication of PiKu 4.20.



Improved Rooting. As part of a study to improve genetic transformation, we found that a compound called 5-azacytidine (AC) improves rooting of micropropagated shoots (Figure 3). Organisms methylate genes to control their activity. AC reduces methylation and we hoped thereby to stimulate expression of genes important to root formation. In the first two experiments, AC plus IBA stimulated more rooting of Gi196-4 and PiKu 4.20 than by either compound alone. AC was not effective on softwood cuttings.

Figure 3. Effect of 5-azacytidine on rooting of 196-4 microcuttings. All cuttings were treated with 1 mM IBA (control) or 1 mM IBA plus the indicated concentration of AC.



Transformation. We use *Agrobacterium tumefaciens* to transfer genes into plant cells. Initially, we are attempting to transfer reporter (GUS) and selection (bar or Npt) genes. Reporter genes "report" their presence in plant cells indicating whether transformation has occurred. Selection genes confer herbicide or antibiotic resistance, which permits growth of transformed cells on antibiotic medium, but kills or prevents growth of untransformed cells. Antibiotics are also used to suppress agrobacterium once transformation has occurred.

Over the past three years, we have refined the regeneration system. The most important result this year was obtaining the plasmid, pBISN1, and finding that it transforms cherry much more effectively than previous vectors we have tried. At the Cherry Research Review, I will show photos of transformed callus and hope to also have photos of transformed shoots of Gi154-4 and 154-7.

In collaboration with Ken Eastwell, WSU-Prosser, we will apply for support from other agencies to begin using this system to transform cherry. In particular, these clones are hypersensitive to PNRSV. PNRSV-resistant clones could be useful in a number of different ways to improve cherry production.

Budget:
Propagation and production of tree fruits and nuts
William M. Proebsting
Project Duration: **2001-03**
Current Year: **2003**
Project Total (3 Years): **$36,000**

Year	2001	2002	**2003 (Current)**
Total	49,978	50,903	**50,497**[1]
Cherry Request	12,000	12,000	**12,000**

Details

	2000-01	2001-02	**2002-03**
Salary, Faculty Research Assistant[2]	26,636	27,972	**28,531**
OPE	14,117 (53%)	13,706 (49%)	**14,266 (50%)**
Student Wages[3]	4,500	4,500	**4,000**
OPE	360 (8%)	360 (8%)	**200 (5%)**
Services and Supplies	4,000	4,000	**3,000**
Travel[4]	500	500	**500**
Total	49,753	50,903	**50,497**[1]

[1] This is the total amount requested to support the entire program, which includes hazelnuts, cherries and pears.
[2]Luigi Meneghelli, Research Assistant
[3]Undergraduates maintain most of the cultures and field plots
[4]Travel to our plots at the Lewis-Brown Farm

Details for Cherry Request:

	2002-03
FRA	6,780
OPE (50%)	3,390
Student Wages	950
OPE (5%)	48
Supplies	713
Travel	119
Total	12,000

CONTINUING PROJECT **YEAR 3/3**
Project #: OSCC-2 (modified)[1]

Title:	Cultivars, rootstocks, training systems and fruit quality evaluation in sweet cherry.
PI's:	Roberto Núñez-Elisea and Lynn Long
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Background

The sweet cherry industry of the Pacific Northwest aims to produce fruit of the highest quality for the fresh market. Many new cultivars and selections have been released in recent years and it is expected that they will provide growers important options including a large range of maturation times, larger and firmer fruit, reduced susceptibility to rain-induced cracking, and self-fertility.

In the Mid-Columbia region of Oregon, sweet cherry trees have traditionally been grown on mazzard rootstock, which produces good yields and fruit quality but forms large trees that lack in precocity. Several promising rootstocks that offer precocity and tree size control have been released in recent years, generating interest among growers. Traditionally, sweet cherry trees have been trained as an open vase. New training systems including the Spanish bush and variations of the central leader system are under experimental and commercial evaluation to assess their usefulness under Pacific Northwest conditions. Development of small trees that facilitate harvesting is important for safety concerns and to make a more efficient use of available labor.

Our efforts aim at developing orchard production systems based on compact, precocious trees that can begin producing commercial, high-quality crops in the 3rd or 4th year. This project is designed to evaluate new cultivars, rootstocks and training systems and determine how these factors affect sweet cherry fruit quality in the Mid-Columbia region.

Objectives

- Evaluate new promising cultivars for tree growth characteristics including branching and fruiting habit, yield, disease tolerance, and bloom and harvest season.
- Evaluate new promising rootstocks and training systems for tree size control, precocity, yield and fruit size.
- Evaluate fruit of different cultivars for quality (firmness, size, ^{o}Brix, titratable acidity, skin color, pedicel color and retention force, handling tolerance).
- Evaluate manual crop load management strategies (i. e., spur thinning, selective de-fruiting) as options to produce larger fruit.

[1] This project has been restructured. Rootstock and training system experiments from last year's OSCC-3 are now part of this project.

Significant findings for 2002

- 8S-3-13: this selection continues to generate much interest due to its earliness (about 5 days before 'Bing'), large fruit (13.6 g), good flavor and firmness, and little rain cracking. Trees produce good crop loads and have good branch angles.

- 13S-42-49: very large, very firm, fruit with good flavor, ripens around mid-July. Fruit detach very easily from pedicels, suggesting that this selection may have potential as a stemless cherry.

- In the NC-140 rootstock trial, yields of Giessen 195-20, Gisela 5, Gisela 7 and Gisela 6 exceeded 46 lb/tree. Average fruit size exceeded 8 g in all rootstocks. Fruit firmness was good for all rootstocks (> 280 g/mm).

Methods

A collection of sweet cherry cultivars and selections is under evaluation in The Dalles and Hood River. Trials are currently being carried out on rootstocks from France and Germany (Weiroot series) in plots in The Dalles with 'Bing' as the scion cultivar. Trees are trained as Spanish bush, open vase or central leader (Vogel) systems. An NC-140 rootstock trial involving 15 rootstocks was established in 1998 and will continue under evaluation for horticultural characteristics.

Evaluation of fruit quality is an important aspect of this project. Fruit samples from different cultivars and selections have been assessed for average fruit weight, size and firmness (FirmTech 2 firmness instrument), sugar (refractometer) and titratable acid content (automatic titrator). Starting in 2003, evaluation will include skin and pedicel color (portable spectrophotometer) and pedicel retention strength (digital force gauge). Fruit quality will be assessed immediately upon harvest and periodically after exposure to different periods of cold storage and room temperature conditions.

Work on manual crop load management will be conducted during 2003. Non-chemical thinning methods including spur thinning ("extinction") and manual fruit removal will be tested on 'Bing'/Gisela 5.

Results

Sweet cherry cultivar collection, The Dalles

Tables 2 and 3 present data on cultivar and selection performance during 2002. Fruit characteristics for each selection correspond to a particular ripeness status and may not necessarily indicate fruit quality at optimum maturity. Fruit firmness was monitored during maturation to determine whether it could be used as a guide in predicting time of harvest. This information is still preliminary and more data will be collected in 2003.

During 2003 we will monitor fruit development and maturation in cultivars and selections of possible commercial potential along with associated quality changes in an attempt to determine harvest criteria.

NC-140 rootstock trial, Orchard View Farms, The Dalles

Performance of 'Bing' on 15 different rootstocks during 2002 is summarized in Table 1. Yields ranged from 14.8 lb/tree in Weiroot 154 to 55.9 lb/tree in Giessen 195-20. High yields approaching 50 lb/tree were also obtained in Gisela 5, 6 and 7. Fruit firmness for all rootstocks was acceptable, ranging from 280 g/mm in Giessen 209-1 to 378 g/mm in Weiroot 154. Differences were observed in fruit maturity among rootstocks at the time of harvest, which may explain in part the variation in fruit firmness.

Table 1. Performance of 'Bing' sweet cherry on 15 rootstocks. Planting established in 1998. The Dalles, 2002.

Rootstock	Yield (lbs/tree)	Fruit wt. (g)	Fruit diam. (mm)	Firmness (g/mm)
Giessen 195-20	55.9	8.9	26.0	297.9
Giessen 209-1	30.3	9.2	27.9	280.0
Giessen 318-17	31.3	9.9	28.9	349.8
Edabriz	32.1	8.3	27.0	283.7
Gisela 4	39.4	8.1	24.7	289.0
Gisela 5	51.3	8.5	27.2	295.4
Gisela 6	46.4	9.6	28.5	319.3
Gisela 7	48.0	8.6	27.3	285.5
P. mahaleb	24.1	9.8	29.0	358.3
Weiroot10	15.2	9.6	27.5	353.1
Weiroot 13	21.6	9.6	28.6	336.7
Weiroot 154	14.8	9.4	28.5	377.7
Weiroot 158	36.2	9.0	26.3	333.2
Weiroot 53	32.2	8.4	27.0	301.6
Weiroot 72	39.4	8.3	27.0	308.2

Hazel Dell rootstock trial, The Dalles

A major portion of this trial has been discontinued and work will continue only with rootstocks showing potential. During 2003, the promising rootstocks Pontaleb, Maxma 14, Weiroot 158 and Weiroot 72, as well as Mazzard (control), will continue to be evaluated for tree growth, yield and fruit quality. Observations will be limited to central leader trees. Steep leader and Spanish bush trees will be managed by grower cooperator.

Spur thinning of 'Bing'/Edabriz to promote fruit size, Hazel Dell, The Dalles

A replicated trial was conducted to determine whether crop load management through spur removal would allow producing large fruit on Edabriz rootstock, which has a strong tendency to overset and produce small fruit. Results were inconclusive due to extremely poor fruit set which was attributed to adverse weather conditions during anthesis. Total yields for the experimental trees were estimated between 10 and 15 lb/tree, when the average production during 2001 was 37 lb/tree. We will attempt to repeat this trial during 2003.

Post-harvest evaluation of modified-atmosphere packaged (MAP) fruit

MAPed fruit samples of 'Cristalina', 'Bing', 8S-3-13, 'Sonata', 'Sandra Rose', 'Sweetheart' and 'Regina' were evaluated to determine quality changes after 10-14 days of storage. Preliminary observations revealed that more than 60% of 'Regina' fruit exhibited darkened pulp spots. Darkening did not cause loss of firmness or tissue integrity although it caused off-flavors and reduced visual appeal. Symptoms are not discernible until fruit is sliced for examination. Apparently, 'Regina' fruit in cold storage alone do not exhibit such pulp darkening, suggesting a sensitivity of this cultivar to modified atmosphere and possibly the need to adjust gas composition during packaging.

Budget[2]

Title: **Cultivars, rootstocks, training systems and fruit quality evaluation in sweet cherry.**

PI's: **Roberto Núñez-Elisea and Lynn Long**

Duration: **long-term**

Current year: **2003**

Current year request: **$26,500**

Original budget request:

Year	Year 2002	**Year 2003**	Year 2004
Total	39,500	**41,000**	

Current year request:

Item	Year 2002	**Year 2003**	Year 2004
Salaries-FRA	27,739	**17153**	
OPE (51.58%)	11,761	**8847**	
Travel to res. plots		**500**	
Total	39,500	**26,500**	28,000

[2] This project has been restructured. Rootstock and training system experiments from last year's OSCC-3 are now part of this project.

Table 2. Fruit characteristics of sweet cherry cultivars and selections. All trees were treated with 25 ppm GA_3. The Dalles, 2002.

Cultivar/selection	Date	Ripeness status	Average fruit wt. (g)	Average fruit diam. (mm)*	Average firmness (g/mm)*	% of fruit*	
						10 row and larger	9 row and larger
8S-3-13	26-Jun	ripe-over	13.6	32.6	285.5	100	92
'Newstar'	26-Jun	ripe	11.7	29.9	217.0	94	52
'Cristalina'	01-Jul	ripe	15.0	29.3	249.7	98	32
'Bing/Mazzard	01-Jul	harvest	9.8	28.5	264.3	80	30
'Bing'/G-5	01-Jul	harvest	12.2	30.9	360.4	100	78
'Bing'/G-6	01-Jul	harvest	11.3	29.9	309.0	98	58
'Sonata'	05-Jul	ripe	13.1	30.9	334.9	96	79
13S-21-07	05-Jul	ripe	12.4	30.8	409.9	100	76
'Sylvia'	05-Jul	ripe	12.1	30.4	299.6	100	68
'Sandra Rose'	09-Jul	ripe-over	15.4	33.7	251.6	100	98
'Attika'	09-Jul	ripe-over	10.0	28.1	288.3	86	6
'Sonnet'	09-Jul	ripe	13.3	31.8	288.6	98	86
13S-18-15	09-Jul	ripe	13.7	32.9	279.2	100	98
4W-11-08	16-Jul	ripe-over	9.9	28.3	321.6	76	27
'Lapins'	16-Jul	ripe	10.3	30.4	354.5	98	60
'Regina'	16-Jul	ripe	12.7	30.7	295.1	100	78
13S-42-49	19-Jul	ripe-under	13.2	32.0	371.5	100	84
'Sweetheart'/G-6	19-Jul	un-ripe	11.3	29.6	250.4	96	54
'Sweetheart'/Maz	19-Jul	un-ripe	12.2	30.7	389.2	94	76
13S-16-29	25-Jul	un-ripe	10.4	29.8	375.1	100	50
'Staccato'	01-Aug	ripe	13.9	32.5	359.8	100	96
'Symphony'	07-Aug	ripe	11.7	29.9	286.0	98	50
13S-21-01	16-Aug	over-ripe	11.1	29.6	238.3	94	46

* Fruit diameter, firmness and percentage according to row size are based on sample of 25 to 50 fruit.

Table 3. Average fruit firmness of sweet cherry cultivars and selections as they approach harvest maturity. Shaded boxes indicate firmness at the time of harvest. The Dalles, 2002.

Cv/selection	20-Jun	24-Jun	26-Jun	01-Jul	05-Jul	09-Jul	16-Jul	19-Jul	25-Jul	01-Aug	07-Aug	16-Aug
8S-3-13	342.9	299.2	**285.5**	249.7								
'Newstar'	224.4	226.9	**217.0**	222	228.1	203.8						
'Cristalina'	357.2	316.0	316.1	**266.9**	287.0	258.3						
'Bing'/Maz.		339.9	301.5	**264.3**								
'Bing'/G-6		326.2	329.8	**309.0**								
'Sonata'	360.8	339.8	324.0	329.4	**334.9**	318.8						
'Sylvia'	355.2	294.0	275.0	302.9	**299.6**	262.5						
'Sandra Rose'		319.2	284.9	302.1	280.5	**251.6**						
'Sonnet'	397.4	345.3	312.2	309.4	299.0	**288.6**						
'Lapins'				373.6	351.8	334.7	**354.5**					
'Regina'					359.9	374.4	**295.1**	290.3	285.2			
13S-42-49					520.9	459.4	392.1	**371.5**				
'Staccato'								400.2	368.0	**359.8**	340.0	243.5
'Symphony'								327.2	345.3	295.9	**286.0**	
13S-21-01								451.5	410.4	390.6	380.2	**238.3**

CONTINUING PROJECT REPORT **YEAR 3/3**
Project # : OSCC –3 (modified)[1]

Title: Tree water use, irrigation scheduling and water management systems in sweet cherry

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Research Assistant: Helen Cahn, OSU, Mid-Columbia Agric. Res. and Ext. Center

Cooperators: Clark Seavert, OSU-MCAREC, Hood River, OR
Matthew Whiting, WSU-IAREC, Prosser, WA
John Selker, OSU Bioengineering Dept., Corvallis, OR
Lynn Long, OSU Extension Service, The Dalles, OR

Objectives

- To measure soil water content in sweet cherry orchards to determine active root depth and quantify tree water use.
- To conduct trials comparing irrigation scheduling based on soil water content vs. a calendar schedule (to begin in 2003).
- To evaluate a woven polypropylene fabric row cover for water conservation and weed control.
- To investigate different water management strategies for water conservation and improved tree water use.

Significant findings for 2002

- Continuous measurement of soil water content within root systems of young (4th leaf) 'Lapins'/Mazzard trees irrigated with micro sprinklers shows that the bulk of the root system is located at 40-50 cm soil depth.
- The use of woven fabric row cover has shown clear effects on tree performance in relation to trees growing without row cover. Effects include greater vigor, improved branching and darker foliage.
- Deficit irrigation of young 'Lapins'/Mazzard trees is showing promise as a technique to reduce vigor and induce precocity of this scion/rootstock combination.

Methods

Measurement of soil water content

Experimental orchards located at the MCAREC in Hood River are being used for this work. Soils are of a sandy loam soil texture, with available water contents of about 13%. Volumetric soil water

[1] This project has been restructured. Cultivar evaluation, rootstock and training system trials are now part of project OSCC-2.

content is measured with a portable probe (Sentek Diviner 2000™) or a continuous soil-water monitoring system (Sentek EnviroScan™). Both systems measure soil water content via vertically placed PVC access tubes installed adjacent to trees, within the area explored by root zones. The Diviner 2000™ is manually operated and collects data at 10-cm intervals though the soil profile. The EnviroScan™ consists of a network of eight permanent probes, each with four sensors at 20, 30, 40, and 60 cm depths. A solar panel and a rechargeable 12-volt battery power the system. Sensors are programmed to collect data at 30-min intervals.

Both systems generate graphs that allow determining tree water use based on the amount of water extracted by roots at different soil depths. The EnviroScan™ provides a detailed graphic time-course of water use at four soil depths due to its ability to collect data continuously (Fig. 1). For a particular soil depth, a line showing a staircase pattern indicates water uptake during the day due to transpiration (declining slope) and lack of uptake during hours of darkness (flat portion). The amount of water used each day can be calculated by adding the amounts of water extracted daily at each soil depth. The rate of daily water depletion corresponds to the daily evapotranspiration rate, as it includes water absorbed by tree roots and water lost to evaporation from the soil surface. The detailed quantitative information obtained by the EnviroSCAN™ system allows determining when and how much to irrigate throughout the growth season.

Use of a polypropylene fabric row cover and irrigation scheduling based on soil water content

A 3-acre plot of 'Regina'/Gisela 6 trees was planted at the MCAREC in April, 2001, to evaluate a woven polypropylene row cover (Earthmat™, Dewitt Co.) and compare irrigation scheduling based on soil water content vs. a calendar schedule. Trees are planted at 10 x 18 ft. and trained to a central leader. The experimental block consists of 16 grids; 8 grids have row covers and 8 do not. Each grid contains a total of 36 trees (4 rows of 9 trees each), with four pollinizer trees (one each of 'Sam', 'Hudson', 'Attika' and 'Starks Gold'). The experiment is a replicated trial set up in a randomized complete block design with a 2 x 2 factorial treatment design (cover or no cover; irrigation based on a calendar schedule or on soil water depletion). Each block contains four grids, one for each of the four irrigation management treatments. Row covers are 8 ft. wide, with 1 ft. of the fabric in the ground on all sides. Irrigation is applied with Netafim microsprinklers delivering 5.2 gal/h, with a wet diameter of 8 ft. Each grid can be irrigated independently. Irrigation during 2001 and 2002 was applied uniformly at weekly intervals to all grids. Approximately 40 gal of water were applied per tree during each weekly irrigation event. Weed control has been by both chemical and mechanical means. Detailed orchard management costs are being recorded to conduct cost/benefit analyses for the irrigation management treatments.

Comparison of irrigation schedules will begin in 2003. Covered and non-covered grids will be irrigated either on a fixed calendar schedule or according to soil water content as determined by a portable probe (Sentek Diviner 2000™). Upon reaching the bearing stage, fruit yield and quality will be determined for each row-covered and non-covered grid. Evapotranspiration rates will be calculated during the different growth stages including bloom, shoot elongation, early fruit development and pre-harvest stage. For irrigation based on soil water content, water will be applied when available water content drops to ≈50%.

An automated soil moisture monitoring system (Sentek EnviroSCAN™) will be installed in late 2002 to continuously record soil moisture content at 20, 30, 40 and 60 cm depths. Sensors will be installed to record soil and air temperature in covered and non-covered rows to determine the effect of temperature on tree growth. Measurements of stem water potential will be made to determine the effect of row cover on tree water status. A newly established weather station will allow determining site-specific evapotranspiration rates for direct comparison with soil moisture measurements.

Deficit irrigation in young 'Lapins'/Mazzard trees to control vigor and induce precocity

Most sweet cherry orchards in the Mid-Columbia area of Oregon are established on Mazzard rootstock. Although Mazzard confers good fruit size and yields, it has the disadvantage of producing large trees that require a long establishment period (often more than 5 years) before first fruiting. Dwarfing, highly precocious rootstocks that begin fruiting by the third leaf are now available for sweet cherries; however, they have often shown a tendency for over-cropping which results in small, less valuable fruit. The approach taken to obtain sweet cherry trees that are compact, precocious, and produce fruit of acceptable size will depend in part on the type of rootstock used. Strategies involving judicious reduction in water supply have shown potential to achieve these goals in several fruit trees and in grapevines and may be effective in Mazzard. Thus, we are evaluating the efficacy of deficit irrigation and partial root zone drying (see report by Matt Whiting), in reducing tree vigor and promoting precocity of 'Lapins' trees grafted onto standard Mazzard rootstock.

Deficit irrigation consists of applying sub-optimal amounts of water to trees to impose a controlled stress. The experimental block was established in 1999, with trees planted at 14 x 16 feet. All trees are being trained to multiple (steep) leaders. The soil is a sandy loam with available water content of about 13%. Irrigation treatments are imposed between May and September. The trial is arranged in a randomized complete block design with 6 replications. Experimental trees are irrigated with micro-sprinklers placed at 56" from tree trunks, delivering 9.5 gal/hour (0.22 inches/hour) with a wet diameter of 14.8 feet. During 2002, irrigation was applied at 7 to 14-day intervals. Three treatments are being tested: control trees are irrigated to replace 100%, 50% or 25% of pan evaporation during the period preceding irrigation. Measurements of tree vigor include trunk cross sectional area (TCSA), shoot length and weight of pruned wood. The level of tree water stress is determined by measuring stem water potential just prior to each irrigation cycle. Soil water content is monitored manually with a portable sensor (Sentek Diviner 2000™) and automatically with a permanent, continuous soil moisture monitoring system (Sentek EnviroSCAN™).

Results and discussion

Measurement of soil water content and location of active root system

Irrigation was applied between mid-June and late September (Figure 2). Soil water content was consistently higher and around saturation (≈ 40 mm, equivalent to 40 %) at 60 cm soil depth, gradually decreasing closer to the soil surface. Root activity was concentrated within 40 to 50 cm soil depth as evidenced by the stair-case pattern of these curves.

Use of a polypropylene fabric row cover and irrigation scheduling based on soil water content

Observations made during 2002 show that fabric row covers help to retain soil water by minimizing soil evaporation, which may potentially result in considerable water savings. Trees with row cover display more vigor than trees without row cover. This may be due to increased soil water retention, lack of weeds, or a combination of both factors. It is possible that root growth has been enhanced under the fabric cover, favoring tree development. Tree shape appears to be influenced by row cover. Trees without row cover tend to display a more columnar shape and have less branching than those without cover. Leaves of trees with row cover were of a darker green color than leaves of trees without row cover. Foliar analyses will determine whether nutritional status has been improved by the use of row covers.

Deficit irrigation in young 'Lapins'/Mazzard trees to control vigor and induce precocity

Results show that irrigating to replace 25% or 50% of pan evaporation has reduced vegetative vigor of young 'Lapins'/Mazzard trees by at least 25% in relation to control trees irrigated by replacing 100% of evaporation rate. Figure 2 shows soil water content for the 0 to 50 cm depth soil profile. Clearly, soil water content reflects irrigation regime, with highest content corresponding to the 100% evaporation replacement treatment. A similar trend was observed for stem water potential immediately prior to irrigation, where 25% or 50% evaporation replacement caused significantly lower values compared to fully irrigated controls, suggesting episodic stress due to water deficit (data not shown). Initial light bloom and erratic fruiting occurred during 2001 and 2002 in some trees of all treatments; however, it has been too scarce to demonstrate that deficit irrigation promotes precocity. Increased flowering levels are expected in 2003, when we expect to be able to determine whether deficit irrigation, besides reducing tree vigor, promotes precocity in young trees grafted onto non-precocious rootstock.

Estimated duration of study: long-term

BUDGET
Project title: Tree water use, irrigation scheduling and water management systems in sweet cherry.
PI: Roberto Núñez-Elisea
Project duration: Continuous
Current year request: $18,500
Original budget request:

Year	Year 2002	**Year 2003**	Year 2004
Total	39,500	**41,000**	

Current year request:

Item	Year 2002	**Year 2003**	Year 2004
Salaries-FRA	27,739	**12205**	
OPE (51.58%)	11,761	**6295**	
Wages			
Equipment			
Supplies			
Travel			
Miscellaneous			
Total	39,500	**18,500**	21,000

This project has been restructured. Cultivar evaluation, rootstock and training system trials are now part of project OSCC-2.

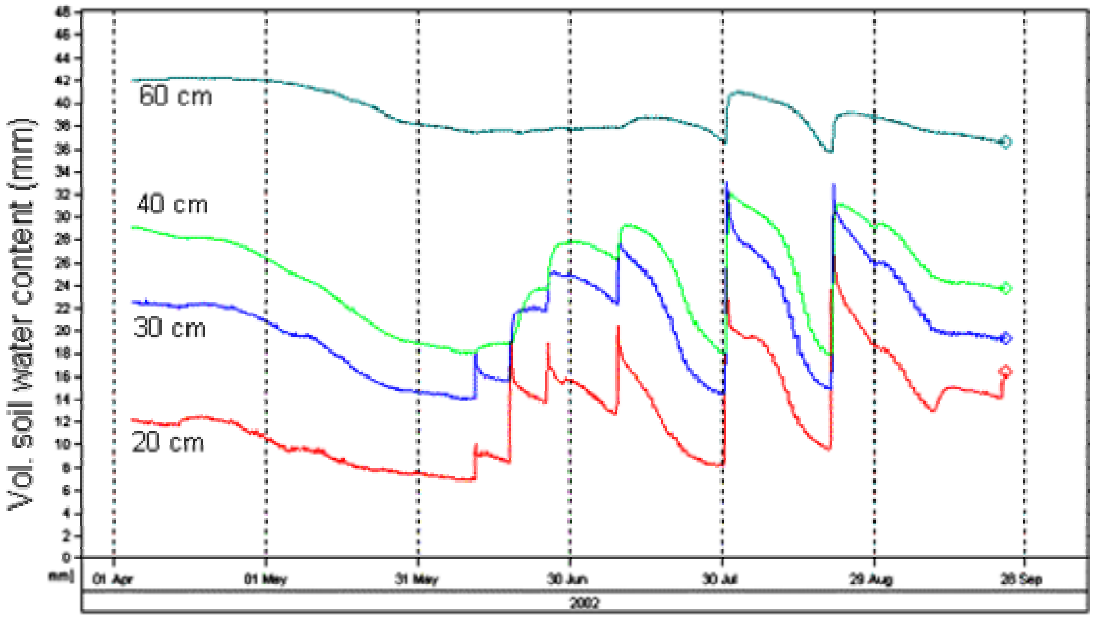

Fig. 1. Soil water content at four soil depths from April to September 2002 as measured with a continuous soil moisture monitoring system (Sentek EnviroScan™). Data correspond to one of eight probes with four sensors. Peaks between mid-May and late September indicate irrigation events. The daily stair-case pattern of lines for 20-, 30-, and 40-cm depths indicate root activity, whereas a smoother daily pattern at 60 cm soil depth indicates minimal presence of active roots. Orchard consists of 4th leaf 'Lapins'/Mazzard trees planted in a sandy loam soil. MCAREC, Hood River, 2002.

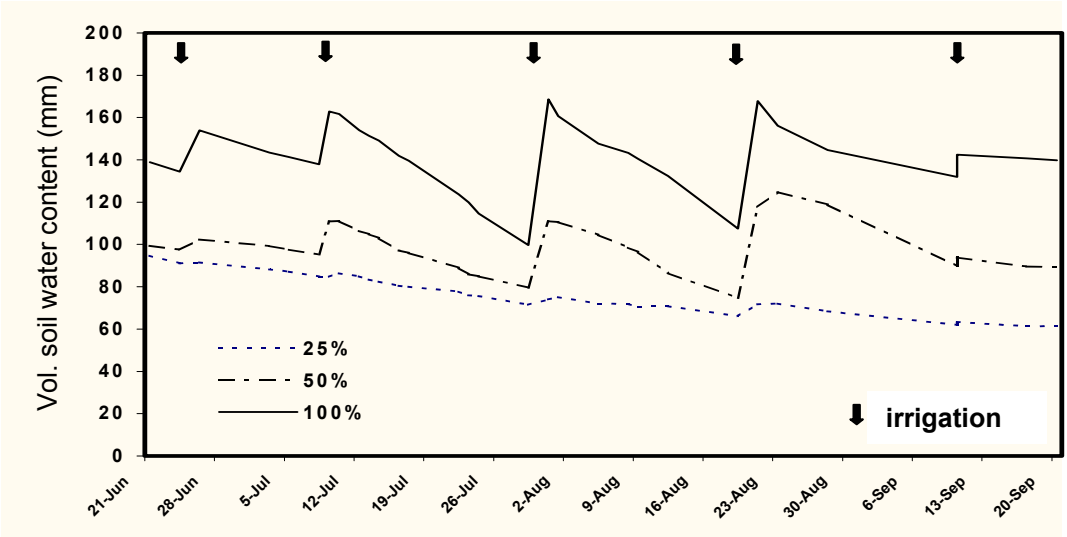

Fig. 2. Seasonal soil water content in the top 50 cm of soil profile during irrigation to replace 25%, 50% (deficit irrigation treatments) or 100% of pan evaporation (control). Orchard consists of 4th leaf 'Lapins'/Mazzard trees planted in a sandy loam soil. Soil water content measured with a portable capacitance probe (Sentek Diviner 2000™). MCAREC, Hood River, 2002.

CONTINUING PROJECT REPORT **YEAR 3/3**
PROJECT NO.: CH-01-17

TITLE: Clonal Rootstock Performance/Evaluations

Principal Investigators: Matthew Whiting
Organization: Irrigated Agriculture Research and Extension Center, WSU-Prosser
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Co-Investigators: G.G. Grove, Assoc. Plant Path., WSU-Prosser
W.E. Howell, NRSP5/IR2 Manager, WSU-Prosser
D.R. Ophardt, Res. Tech. Supervisor, WSU-Prosser

OBJECTIVES:
Comprehensive rootstock research is necessarily a long-term project. However, various components of the objectives will be completed annually.

1. Continue evaluation of the NC-140 regional project trial ('Bing' on 17 new rootstocks) established in 1998 for horticultural and physiological evaluations and fruit quality. Projected trial duration is 10 years.

2. Continue evaluating vigor and cropping performance of other orchard trials with key PNW cultivars on various rootstocks: e.g., 'Bing' on 5-6 different Gisela rootstocks in grower trials representing diverse production locations (planted in 1994-95); 'Chelan', 'Tieton', 'Cashmere', 'Liberty Bell', and 'Columbia' on Mazzard, Mahaleb, 'Colt', 'Edabriz', and various Gisela and Weiroot rootstocks (planted in 1998).

3. Analyze the physiology of interactive rootstock/scion horticultural traits (e.g., canopy leaf area, yield efficiency, precocity, graft compatibility). On-going as personnel allows.

SIGNIFICANT FINDINGS:
1998 NC-140 Trial Rootstocks Training and growth of the 1998 NC-140 trial trees continued with most trees yielding a significant crop in 2002. Significant differences in fruit yield and fruit size were evident in 2002.

In addition, from the 1998 NC-140 rootstock trial in 2002:

- the following are dwarfing rootstocks (i.e., exhibit vigor reduction of 40 – 50% compared to Mazzard): W53, W72, W154, Edabriz, Gi209/1, and Gi473/10

- yield was greatest in Gi209/1, Gi473/10, W72, and Edabriz (22 – 24 kg/tree), and lowest in W154 and W53 (10 - 12 kg/tree)

- the following are semi-dwarfing (i.e., 70 –80% of Mazzard): Gi195/20, Gi5, Gi7, and W158

- yield was greatest in Gi7 (42 kg/tree), intermediate for Gi5 and Gi195/20 (33-38 kg/tree), and lowest for W158 (18 kg/tree)

- the following are vigorous (i.e., ≥90% of Mazzard): W13, W10, Gi6, Mahaleb, Gi318/17, and P-50

- yield was greatest for Gi6 (41 kg/tree), intermediate for Gi318/17 (26 kg/tree) and lowest for Mazzard, W13, W10, Mahaleb, and P-50 (4 - 16 kg/tree)

- there is no clear relationship between scion vigor and fruitfulness among these rootstocks

- a slight negative relationship existed between fruit yield and quality

- no clear relationship existed between tree vigor and quality

- yield efficiency was closely and negatively related to fruit quality ($r^2 = 0.83$)

- fruit quality was best on Mahaleb (8.3 g/fruit, 24.4 ^{o}brix) and worst on Gisela 7 and 195/20 (6 g/fruit, 17 ^{o}brix)

- the rootstock that provided the best combination of yield and quality in 2002 was Gi318/17 (26 kg/tree, 8.2 g/fruit)

'Chelan' Rootstock Trial The 1998 'Chelan' rootstock trial continued to exhibit differential reactions between rootstocks in 2001/2002. One complete replication (4 trees) on Mahaleb were lost to gopher damage during the winter; no trees on other rootstocks were damaged. Although growth was generally excellent on all rootstocks, the trees on Mahaleb died. About 6% of the trees on Mazzard exhibit a health problem and only 2% of the trees on Colt. None of the trees on Edabriz, Gisela 6, GI 209/1, or GI 195/20 yet exhibit any unusual symptoms. All of the trees on Gisela 5 exhibit a minor degree of premature leaf coloration and/or premature defoliation. These results with Mahaleb confirm several grower observations of tree mortality on Mahaleb.

WSU Variety Rootstock Trial Varieties included in this trial are: Chelan, Tieton, Benton, Selah, Rainier, and elite selections PC 8011-3, PC 7147-9, and PC 7903-2. 2002 represented the first significant crop on most rootstocks. Rootstock impacted scion precocity and fruit quality tremendously. In general, fruit quality was excellent with a high percentage of fruit being 10.5-row and larger.

- fruit soluble solids were highest on Edabriz and Gisela 209/1 (~ 21 ^{o}brix) and lowest on Gisela 5 and 6 (~ 19 ^{o}brix)

- individual fruit mass was similar for Edabriz and Gisela 5 and 6 (~ 9.3 g), and highest on Gisela 209/1 (~ 10.9 g)

- yields were highest on Gisela 6 and 5 (22 and 19 kg/tree, respectively), 50% less on Edabriz, and 70% less on Gisela 209/1

- fruit row-size distribution was best on Gisela 209/1 (98% 10.5-row and larger) and worst on Gisela 5 (87% 10.5-row and larger)

METHODS:
The 1998 NC-140 plot was planted at WSU-Prosser's Roza Experimental Unit, with 'Bing' as the scion cultivar and 'Van' as the pollinizer, on the German rootstock series Gisela 4 (GI 473/10), Gisela 5 (GI 148/2), Gisela 6 (GI 148/1), Gisela 7 (GI 148/8), GI 195/20, GI 209/1, and GI 318/17; the German rootstock series Weiroot 10, W13, W53, W72, W154, and W158; Edabriz (France); P-50 (Japan); and Mazzard and Mahaleb seedlings as controls. There are 8 replications/rootstock, with guard tree around the plot perimeter, and tree spacing of 19.5 x 19.5 ft (6.0 x 6.0 m) to reduce the potential influence of neighboring trees. Irrigation by microsprinklers and frost protection by wind machine were installed. A duplicate plot was planted for potentially destructive analyses, such as physiological stress treatments. Improved estimates of rootstock influence on canopy vegetation (a key measure of potential fruit sizing capability) will be made with a non-destructive, portable, microprocessor-based leaf area meter to be obtained in 2002.

A new plot of 'Chelan' on Mazzard, Mahaleb, 'Colt', 'Edabriz", and various Gisela rootstocks was planted in 1998 to document whether industry concerns of certain graft incompatibilities with this important new variety are warranted. A small plot of 'Lapins' on Mazzard and Mahaleb was also planted to examine graft incompatibility potential. If and when evidence of incompatibilities arise, tissue samples will be taken from respective graft unions for biochemical analysis and investigation of the potential for developing a screening test for other incompatible rootstock/scion combinations.

Two new plots of WSU-Prosser varieties (including Benton, Selah, Glacier, and Tieton) and elite selections (including 8011-3, 8011-7, 8012-9, 8014-1, 7217-2, 7306-1, 8007-2, and 8005-1) on the new PiKu series (selections 1 and 3) of rootstocks, the Gisela series (including 5, 6, and 12), Mazzard, and Mahaleb were planted in 2002. Growth, fruiting, fruit quality, graft compatibility will be monitored in these plots.

RESULTS & DISCUSSION:
This project generates critical clonal rootstock/scion performance information that is providing new strategies for early-producing, high-yielding, efficiently-harvested PNW sweet cherry orchards. The screening for incompatibilities may help prevent economic losses due to unforeseen graft incompatibility of new rootstocks, and screening for adaptability to environmental extremes may help prevent catastrophic economic losses in new or mature orchards. The analysis of rootstock influence on important horticultural characteristics assists in developing management strategies for maintaining productivity in high-density orchards. In addition to annual NC-140 project reports on vigor and yield, 5-year cumulative studies will be compiled after 5 and 10 years in the 1998 trial. Information transfer will occur through research reports at industry meetings (e.g., Cherry Institute, IDFTA), on-site grower evaluations of IAREC and industry cooperator research plots, and publication of results and recommendations in industry (e.g., Good Fruit Grower) and scientific periodicals (e.g., Fruit Varieties Journal, HortScience, etc.).

Publications
Lang, G. A. 1999. Managing for possible mixup of Gisela 5 and Gisela 6 rootstocks. The Fruit Grower News 38: 20-21.

Lang, G.A. 2000. Precocious, dwarfing, and productive – how will new cherry rootstocks impact the sweet cherry industry? HortTech. 10: 719-725.

BUDGET:

Title: Clonal Rootstock Performance/Evaluations
PI: Matthew Whiting
Project Duration 3 years
Project total (3 years) $52,706
Current year request: $17,746

Year	2001	2002	**2003**
Total	$15,580	$19,380	**$17,746**

Current year breakdown

Item			
Salaries[1]	5,897	5,797	**6,083**
Benefits (28%)	2,123	1,623	**1,703**
Wages[2]	3,500	6,000	**6,000**
Benefits (16%)	560	960	**960**
Equipment		2,000	
Supplies[3]	3,000	2,500	**2,500**
Travel[4]	500	500	**500**
Miscellaneous			
Total	$15,580	$19,380	**$17,746**

1 1/6 annual salary for Mr. Efrain Quiroz
2 Time slip wages for harvest, data collection, and fruit quality and laboratory analyses.
3 Supplies for fruit evaluations
4 Travel to plots

CONTINUING PROJECT REPORT **YEAR 2/3**
PROJECT NO.: CH-02-201

TITLE: Alternative Water Management Strategies for Sweet Cherries

Principal Investigators: Matthew Whiting, Assistant Horticult., WSU-IAREC
Roberto Núñez-Elisea, Horticult., OSU-MCAREC

Cooperators: Jim McFerson, WTFRC, Wenatchee
Denny Hayden, Pasco

OBJECTIVE:

- Elucidate the effects of deficit irrigation and partial rootzone drying on sweet cherry vegetative growth, fruit quality, and leaf and whole-canopy transpiration and carbon assimilation.

SIGNIFICANT FINDINGS:

- neither deficit irrigation strategy significantly affected fruit quality compared to the control (i.e., similar quality fruit were grown using less water)
- fruit and shoot growth rates were not affected by reduced water input
- postharvest net photosynthesis was reduced by DI (ca. 50%) but unaffected by PRD
- stomatal conductance was similar for control and PRD and about 20% lower for DI
- water use efficiency (g CO_2/g H_2O) was highest for control and PRD and lowest for DI
- DI-treated trees exhibited premature leaf senescence compared to control and PRD which were similar
- shoot leaves senesced prior to spur leaves
- among rootstocks, Gisela 5 trees senesced earliest
- leaf 'greenness' (i.e., SPAD meter readings, related to leaf N) was significantly less in DI compared to control and PRD which were similar
- leaf water potential in August was highest in control, and lowest for DI
- for PRD, alternating between rootzones was necessary every 2 – 3 weeks

METHODS:

The effects of two season-long, reduced-input irrigation strategies (deficit irrigation and partial root zone drying) will be investigated. Experiments will be conducted on mature bearing 'Bing' cherry trees at the WSU-Roza experimental orchards, the MCAREC orchards in Hood River, and at grower-collaborator orchards (as identified) in subsequent years.

WSU-ROZA trial:

All treatments will be applied at weekly intervals with under-tree microsprinklers (1/tree).

Control: Water sufficient to replace 100% of that lost by evapotranspiration (Et) will be applied to the entire rootzone. Et is calculated using the Washington Irrigation Scheduling Expert (W.I.S.E.).

Deficit irrigation (DI): Irrigation water will be applied to the entire rootzone but at 50% Et replacement.

Partial root zone drying(PRD): Irrigation water will be applied at 50% Et replacement but only to one half of each tree's root zone (i.e., alleyway) during each irrigation event. Subsequent irrigation events will alternate between root zone halves.

The following data will be collected from treated and control trees at regular intervals throughout the duration of the experiments:

- trunk-cross sectional area, shoot length, leaf area (spur and shoot), leaf water potential, fruit diameter, soil water content

Total water application will be compared among treatments by timing irrigation events. At harvest, tree yield and fruit quality (weight, size, soluble solids, and firmness), will be determined from each tree.

In addition, whole-canopy gas exchange (transpiration and net photosynthesis) of selected trees will be determined. Previous research at the IAREC has shown that sweet cherry yield and fruit quality are limited by the production of photosynthates (see, Report "Quantifying limitations to balanced cropping"). Therefore it is critical to determine whether water application can be reduced without negatively impacting whole-canopy carbon assimilation.

Trials will be continued in subsequent years to examine carryover effects of reduced water inputs.

RESULTS AND DISCUSSION:
Interestingly, in this first year, fruit quality and yield were similar among all treatments (Table 1, Figure 1). Therefore, water application may be reduced without affecting grower returns. However, the 2002 growing season began with a fully water-saturated soil profile because irrigation water was used for frost protection in this trial. Had irrigation water not been used, the deficit-induced drawdown of soil water content may have been hastened and affected fruit yield and quality in 2002. It appears, based on reductions in net photosynthesis (Table 2) and premature leaf drop, that yield and quality potential of DI trees in 2003 may be reduced due to low carbon and nitrogen reserves. Critical to the potential for deficit irrigation is elucidating the carryover effects of 2002 treatments to 2003. Water stress is known to increase flower bud initiation and reduce vegetative growth in other species - a particularly dangerous combination for trees that may already have high fruit-to-leaf area ratios and reduced fruit quality (e.g., Gisela-rooted trees).

Table 1. Effect of deficit irrigation (DI) and partial rootzone drying (PRD) on yield and fruit quality of 8-year-old 'Bing' sweet cherry trees. Data is averaged across all rootstocks (Mazzard, Gisela 5 and Gisela 6). Means followed by the same letter within columns are not significantly different by LSD ($P < 0.05$).

Treatment	Tree yield (kg)	Fruit Mass (g)	Soluble solids (%)	Firmness (g/mm)
Control	21.5 a	6.3 a	19.8 a	288 a
DI	22.2 a	6.4 a	20.6 a	288 a
PRD	23.1 a	5.8 a	20.7 a	268 a

Table 2. Effect of deficit irrigation (DI) and partial rootzone drying (PRD) on leaf gas exchange of 'Bing'/Gisela 6 sweet cherry trees. Data were collected on fully sunlit leaves on 17 September (n=5). Means followed by the same letter within columns are not significantly different by LSD ($P < 0.05$).

Treatment	Net photosyn. ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	Transpiration ($mmol \cdot m^{-2} \cdot s^{-1}$)	Stomatal conductance	Water use efficiency ($g\ CO_2/gH_2O$)
Control	5.9 a	5.2 a	135 a	0.0028 a
DI	3.1 b	3.8 b	95 b	0.0020 b
PRD	6.0 a	4.8 a	125 a	0.0031 a

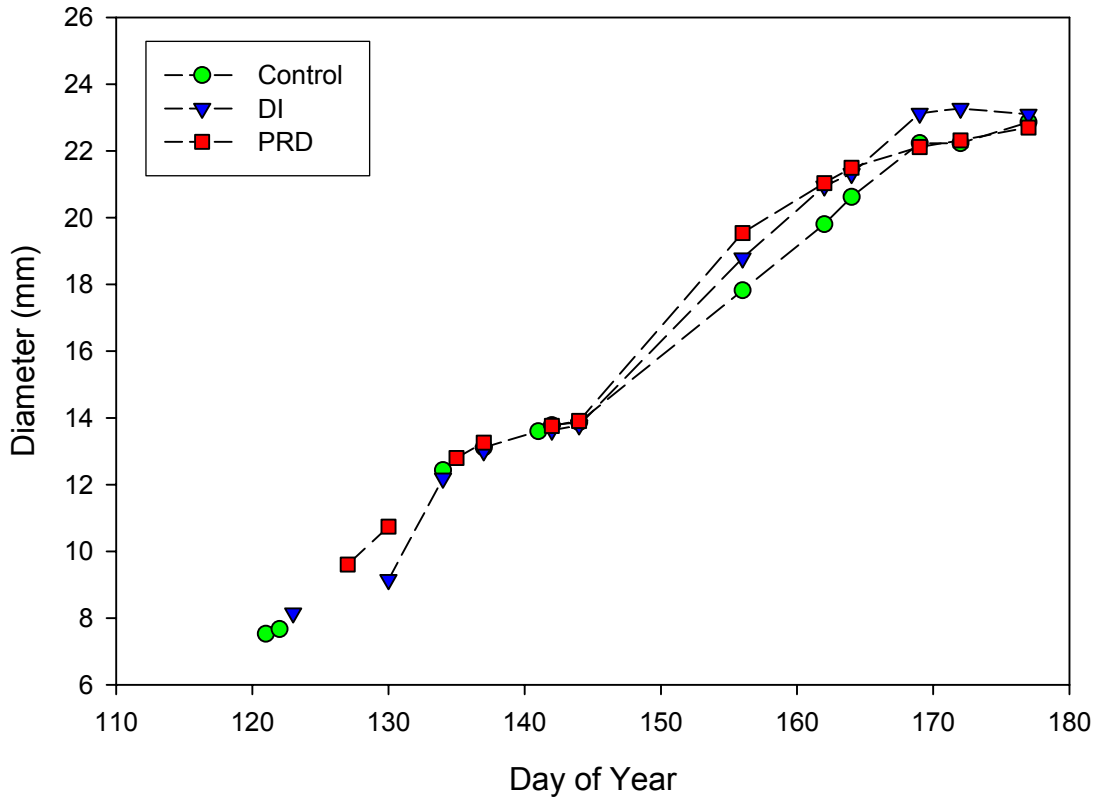

Figure 1. Seasonal trend in equatorial diameter of 'Bing' sweet cherry fruit subjected to deficit irrigation (DI) and partial rootzone drying (PRD).

BUDGET:

Title: Alternative Water Management Strategies for Sweet Cherries
PI: Matthew Whiting
PROJECT DURATION: 3 Years
Project total (3 years) $41,920
Current year request: $10,960

Year	2002	**2003**	2004
Total	$20,000	**$10,960**	$10,960

Current year breakdown

Item			
Salaries			
Benefits (30%)			
Wages[1]	6,000	**6,000**	6,000
Benefits (16%)	960	**960**	960
Equipment	10,040		
Supplies[2]	1,500	**2,500**	2,500
Travel[3]	1,500	**1,500**	1,500
Miscellaneous			
Total	$20,000	**$10,960**	$10,960

[1] Time slip wages for data collection and fruit quality/laboratory analyses.
[2] Whole-canopy chamber and laboratory supplies.
[3] Transport of shared equipment between MCAREC and IAREC.

CONTINUING PROJECT REPORT **YEAR 3/3**
PROJECT NO.: CH-01-16 (13C-3355-5202)

TITLE: Intensive Sweet Cherry Orchard Management

Principal Investigators: Matthew Whiting
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Co-Investigators: D. Peterson, USDA-ARS, Kearneysville, WV
D.R. Ophardt, Res. Tech. Supervisor, WSU-Prosser
Cooperators: D. Hayden, Pasco, WA
B. Harris, Moxee, WA

OBJECTIVES:

1. Plant a new orchard for the development and evaluation of management practices (e.g., specific training/pruning strategies and growth regulator applications) that facilitate mechanical harvest of sweet cherries for the fresh market.

2. Continue to evaluate the interactions between high density pruning/training systems and trees on various rootstocks for precocity, yield efficiency, fruit quality and other horticultural characteristics. Remaining trial duration is two to three years.

3. Refine high density orchard management techniques (e.g., pruning/training systems) for 'Bing' and 'Rainier' trees established in 1995 on dwarfing and non-dwarfing rootstocks. Remaining trial duration is two to three years.

4. Develop and apply cultural techniques, such as developmental bud and branch management, growth regulator applications, to achieve smaller trees on non-dwarfing rootstocks in new WSU or cooperators' orchards.

Significant findings:
Cultivar x Rootstock x Training System:
In 2002 we compared vegetative characteristics and fruit quality of 'Bing' trained to 4 distinct systems: the free-standing central leader (CL) and Spanish bush (SB) with the trellised palmette (P), and Y-trellis (Y).

- Among training systems and across rootstocks:

- fruit quality was lowest for P-trained trees (5.7 g/fruit, ~ 50% ≤ 12-row), and best for SB-trained trees (6.7 g/fruit, ~ 20% ≤ 12-row)
- fruit quality was negatively related to tree yield
- fruit yield was significantly lower (ca. 30%) from SB trees compared to the other three systems
- trees trained to CL and P systems were the least vigorous
- yield efficiency (kg/cm^2 TCSA) was significantly less for SB trees compared to all other training systems

- Among rootstocks and across training system:
  fruit quality was best on Mazzard and worst on Gisela 5
- yield was highest on Gisela 6 (~ 26 kg/tree, 9 tons/acre) and ca. 20 and 50% less from Gisela 5 and Mazzard, respectively
- despite ~ 90% higher total yields from Gisela 5, Mazzard-rooted trees yielded a similar quantity of ≥ 11-row fruit per tree
- Mazzard was the most vigorous followed by Gisela 6 (20% less) and Gisela 5 (45% less)
- yield efficiency was greatest on Gisela 5, 17% less on Gisela 6, and 70% less on Mazzard

- Across all rootstock/training system combinations, yield efficiency and fruit size were correlated closely (r^2=0.83) and negatively

- The top three system/rootstock combinations for yield and quality were: Gisela 6 trained to either Spanish Bush or Central Leader, and Gisela 5 trained to Spanish Bush

Fundamental Cropping Components:
In 2002 we studied how canopy architecture affects fundamental components of cropping and fruit quality including number of spurs per tree, flower buds per spur, length of wood per tree, and trunk cross-sectional area. From these data, spur/bud density (spurs/buds per cm wood) and potential cropping density (fruit per tree) were estimated. With this knowledge, we will better understand the effects of training system on tree productivity and be able to develop system-specific management techniques.

- Across all rootstocks, Y-trellis had the highest number of spurs per tree (~750), SB and P were similar (~700), and CL had the fewest (~650)

- CL trees had the highest number of buds per spur (3.2) and SB had the fewest (2.1)

- Therefore, potential fruit per tree was highest for CL (due to high buds/spur), intermediate for P and Y, and lowest for SB (due to low # buds/spur)

- Y trees had the most wood, SB were intermediate, and P and CL had the least

- Spur density was therefore highest for P and the lowest was for Y trees

- Among all combinations, CL Gisela 6 is potentially the most productive and Mazzard trained to SB was the least productive

Methods:
A new high-density orchard (3 acre) will be designed and planted specifically to facilitate mechanical harvest of fruit. Several cultivar/rootstock combinations will be planted including Bing, Chelan, Columbia, Liberty Bell, Sweetheart, and Tieton on Gisela 5, 6, and 3 (209/1), Edabriz, Weiroot 72 and 158. Different high density orchard strategies will be applied, including training (e.g., variations of the Y-trellis, non-trellised) and the use of plant bioregulators. These orchard system variables will be studied for their influence on tree/system precocity, fruit quality, ease/cost of maintenance, efficiency of harvest, and long-term productivity.

A 4-acre (2ha) high density orchard (360tress/acre) of ‘Bing’ and ‘Rainier’ on Mazzard (full size), and Gisela 5 (50% size), Gisela 6 (Full size), Gisela 7 (55% size), and Gisela 11 (75% size) was established in 1995 at WSU-Prosser’s Roza Experimental Unit with microsprinkler irrigation and

wind machine frost protection. Eight training systems, four trellised (single-plane palmette, double-plane "Y", single-plane oblique leader, and single-plane central leader) and four self supporting (multiple leader bush, central leader spindle, central leader axe, and standard multiple leader), were imposed in a randomized block design. Size control, precocity, yield efficiency, fruit quality and other horticultural characteristics are being evaluated relative to both rootstock/scion combinations and rootstock/training system interactions.

Several smaller high density orchards have been planted at the Roza Experimental Unit for short-term studies of specific intensive management practices as trees have been available. These include: 'Bing' and 'Rainier' on Mazzard and Gisela 5, Gisela 6, Gisela 7, and Gisela 11 rootstocks, planted in 1995 on a single plane trellis at trunk anglesthat vary by 15° increments from 30° to 90°, to examine specific training vs. cropping responses (precocity, fruit quality, and flower bud development vs. shoot growth); a very high density orchard of 'Bing' on Gisela 1 (GI 172/9), planted in 1996 and trained to a central leader spindle to examine canopy architecture as influenced by selected bud or shoot removal, as well as renewal pruning on fruit quality since Gisela 1 is prone to severe overcropping and poor vigor; and high density orchard plots of 'Chelan', 'Attika', 'Lapins', and 'Regina' planted in 1998 on standard rootstocks and trained to either a multiple leader bush or central leader spindle training system to examine growth and precocity responses of these new cultivars to high density training systems. Selective bud removal strategies on young trees in these, and in grower/cooperator orchards will continue to examine the potential for non-Promalin branch development, enhancement of precocity on standard rootstocks, and balancing of reproductive vs. vegetative vigor on precocious rootstocks.

Results and Discussion:
Sweet cherry orchards are being planted at higher tree densities to improve orchard efficiencies (labour in particular) and economic returns. In addition, the prospect of mechanical harvest of sweet cherries for sale in a premium, fresh market, creates the need for novel orchard systems trials to better understand key growth and cropping components (*e.g.*, cultivar, rootstock, and training system and their interactions). This project provides critical, practical information relating sweet cherry cropping performance to specific intensive training and orchard management decisions under PNW conditions. In addition, the potential impact of unique production strategies for mechanical harvest of fruit will be documented.

Our results show that training system (across all rootstocks) can significantly affect yield and fruit quality (Table 1). Spanish Bush-trained trees were less productive (total tree yield) compared to the other architectures although this system yielded the best quality fruit and matched the higher yielding trees for ≥ 11.5-row fruit yield. Indeed, almost 80% of fruit from SB trees were in the larger category compared to 60% for CL, 47% from P, and 49% from Y trees.

In general, fruit quality was poor. This reflects largely overproduction on the Gisela-rooted trees (see Table 2). Future research will focus on refining specific management techniques (*e.g.*, pruning, fertilization strategies, growth regulators) that maximize yield and quality *within* a given orchard system.

Table 1. Effect of training system on fruit quality and productivity of 8-year-old 'Bing' sweet cherry trees. Means followed by the same letter within columns are not significantly different by LSD ($P < 0.05$).

Training System	Tree Yield (kg)	Fruit Mass (g/fr)	Fruit Yield ≤ 12-row (kg)	Fruit Yield ≥11.5-row (kg)	TCSA (cm^2)	Yield Efficiency
Central Leader	21.4 a	6.2 a	8.7 a	12.8 a	183 b	0.129 a
Spanish Bush	15.3 b	6.6 a	3.3 b	12.0 ab	216 a	0.082 b
Palmette	22.4 a	5.7 b	11.9 a	10.5 ab	182 b	0.134 a
Y-trellis	19.7 a	6.1 a	10.1 a	9.6 b	207 a	0.112 a

Rootstock significantly affected fruit quality, yield, tree vigor, and yield efficiency (Table 1). These results support data from 2001. In general, trees on Mazzard were larger and yielded fewer, higher quality fruit compared to Gisela 6 and 5. Trees on Gisela 6 yielded significantly more fruit of slightly better quality than trees on Gisela 5. Clearly the implementation of 'standard' management practices in 'Bing'/Gisela 5/6 trees leads to high yields of poor quality fruit. In 2001, less than 30 and 20% of harvested fruit were 11-row or larger for Gisela 6 and 5, respectively. In 2002 however, 57 and 45% of fruit were ≥ 11.5-row. This likely reflects the negative relation between fruit quality and crop load (see report on Quantifying Limitations to Balanced Cropping) because tree yields were almost 30% less in 2002. Over three-quarters of fruit from Mazzard-rooted trees were ≥ 11.5-row in 2002.

Table 2. Effect of rootstock on fruit quality and productivity of 8-year-old 'Bing' sweet cherry trees. Means followed by the same letter within columns are not significantly different by LSD ($P < 0.05$).

Training System	Tree Yield (kg)	Fruit Mass (g/fr)	Fruit Yield ≤ 12-row (kg)	Fruit Yield ≥11.5-row (kg)	TCSA (cm^2)	Yield Efficiency
Gisela 5	20.8 b	5.7 b	11.8 a	9.3 b	137 c	0.159 a
Gisela 6	26.1 a	6.1 b	11.2 a	14.8 a	202 b	0.132 b
Mazzard	12.3 c	6.7 a	2.7 b	9.5 b	252 a	0.052 c

Budget:

Title: Intensive Sweet Cherry Orchard Management
PI: Matthew Whiting
Project duration: 2001-2003
Project total (3 years) $42,926
Current year request: $18,246

Year	2001	2002	**2003**
Total	$10,500	$19,180	**$18,246**

Current year breakdown

Item			
Salaries[1]		5,797	**6,083**
Benefits (28%)		1,623	**1,703**
Wages[2]	6,000	6,000	**6,000**
Benefits (16%)	960	960	**960**
Equipment		1,800	
Supplies[3]	3,000	2,500	**2,500**
Travel[4]	540	500	**1000**
Miscellaneous			
Total	$10,500	$19,180	**$18,246**

1 1/6 annual salary (2 months) for Mr. Efrain Quiroz
2 Time slip wages for harvest, data collection, and fruit quality analyses
3 Supplies for laboratory analyses
4 Travel to plots

CONTINUING PROJECT REPORT
Project # OSCC-1

Project title:	Horticulture management systems for high value fresh and brine cherries
PI:	Anita Nina Azarenko
Organization:	Dept. of Horticulture, Oregon State University, 4017 ALS, Corvallis, OR 97331-7304
Research assistant:	Annie Chozinski, Department of Horticulture, Oregon State University
Cooperators:	Dr. Roberto Nunez-Elisea, MCAREC, Oregon State University Mr. Don Nusom, Nusom Orchards, Gervais, OR Dr. Frank Kappel, Agriculture Canada, Summerland, BC Dr. Robert Anderson, Cornell University, Geneva, NY

Objectives for 2003-2004:

1. Identify cherry cultivars suitable for the processing cherry industry (e.g. brine, freezer) and those that may have potential for fresh market production in the Willamette Valley.
2. Evaluate cherry genotypes for *Pseudomonas* tolerance by a bloom and leaf assay and field ratings.
3. Appraise new potential rootstocks for commercial acceptability in Willamette Valley sweet cherry production systems.
4. Assess the influence of burning to induce budbreak and its time of application on branch angle, precocity, production, fruit size and quality, and the presence of bacterial canker.
5. Evaluate two growth regulating chemicals and a reflective mulch for their influence on cherry bloom delay or enhancement, and subsequent maturity and quality of fresh cherry fruit.
6. Assess the effect of Retain on stem retention of 'Skeena' and 13S 21-01.

Significant Findings:

- *1996 Dark cherry cultivar trial*- The most promising commercial fresh cherry cultivars and advanced selections in this trial are 'Sandra Rose', 'Staccato', 'Sylvia', 'Regina', 'Skeena', 'Symphony', 13S 49-24, 13S 16-29, and 13S 21-01, and. The low stem pull force (<500 g) of 'Skeena', 'Symphony' and 13S 21-01 fruit is of concern for post-harvest stem retention. However, these cultivars and those with intermediate stem pull force (600-650 g) ('Sylvia', 13S 49-24, and 13S 16-29) may make these genotypes more suitable for stemless cherry production systems.

- *1998 Blush cherry trial*- The most promising selections this year that may be suitable for the brine industry include NY252, NY8182, NY9295, 13N 07-39, 'Sweetheart', and 'Stardust'. Larger fruited selections when grown on Gisela 5 that may have fresh market potential include NY307, 13N 07-39, 13N 07-32, and 2N 31-19.

- *1998 NC-140 'Bing' rootstock trial*- Of the rootstocks that are commercially available, Gi5 and Gi6 are 4-5 times more productive than Mazzard and had larger fruit size. Stem pull force was the lowest for fruit harvested from Mazzard trees.

- *Bacterial canker tolerance*- 'Staccato', 13N 14-22, and 'Cristalina' developed the most symptoms of the dark cherries. 'Newstar, 'Sandra Rose', 'Bing', 'Sonata', 'Skeena', 'Sylvia', 'Regina', 'Symphony', 13S 17-40, 13S 18-15, 13S 42-49, 8S 03-13, 4W 11-08, 13S 21-01 have developed no or very few symptoms. In the blush trial, 'Stardust', NY13688, 13N 07-39, and NY8182 had no symptoms. 'Bing' trees grafted onto Gisela 4, Gi195-20, Gisela 6, Gisela 5, and 'Edabriz' rootstocks have the highest number of infected scaffolds.

- *1995 Gisela rootstock trial*- The trunk-cross sectional area of Mazzard was more than twice as large as Gisela 1 to ~5 times greater than Gisela 6. Fruit size was largest on Gisela 1 and smallest on Gisela 5. Gisela 6 and 8 had the highest number of suckers. Stem pull force was the lowest for fruit harvested from Mazzard rootstock.

- *1998 Weiroot rootstock trial*- W13 trees produced 6-9 times more fruit than W53, W154, and W158 trees. Fruit size and firmness were excellent. Fruit harvested from W158 had the greatest incidence of cracking. Stem pull force was significantly lower for fruit harvested from Mazzard and W53 trees.

- *2000 Branch angle trial*- Cluster no. tended to decrease as branch angle decreased. Yields were significantly higher on trees where branches were trained to the horizontal. Training 'Regina' trees to 60-90° from the leader will induce heavier flowering and cropping.

- *1999 Interstem trial*- MxM60 low- or high-grafted trees had the largest TCSA. Low–grafted Gisela 5, regardless of trunk genotype (MxM60 or Royal Ann), were intermediate in TCSA. The smallest TCSA's were found with trees where Gisela 5 is the trunk (interstem or high grafted).

- *2001 'Lapins' notching trial*- Notching at or before green tip + one week induced the highest amount of budbreak.

- *2001 'Lapins' disbudding/shoot removal trial*- Disbudding at different times had no influence on budbreak.

- *2002 'Sweetheart' leader burning trial*- A preliminary study was begun with a soldering iron to burn the central leader above buds at green-tip + 2 weeks to determine the influence on bud break, shoot angle and bud break. All burn treatments appeared to increase branching at the desired locations and produced a similar result. No gumming was observed at the site of the burns.

- *Sweet cherry fruit growth curves*- The different maturity times of cherry cultivars are influenced by the duration of the pit hardening stage and the rate of growth during final swell.

Methods:

1. Train, maintain and obtain data on yield, fruit size, tree vigor and other relevant data from the existing cherry cultivar trials which include:

   1996 BC dark cherry trial (0.15 ha of low-budded central leader trees)

   1998 Blush cherry trial (0.35 ha of low-budded central leader trees)

2. Each planting includes four replicates of three trees of each cultivar, rootstock, and training system combination.
   Top-worked trees: The rootstocks in the top-worked low-density trial are: Gi196-4, MxM14, MxM60 and Mazzard seedling. 'Royal Ann', 'Sweetheart' and 'Stardust' will be top-worked onto these rootstocks. The training systems we will apply in this trial include: free standing, top-worked trees that are trained to a multiple leader tree and central leader (single multiple bud graft)

trees. The top-worked trees were planted at 18' x 18', in anticipation of mechanical harvest. The total number of trees in this planting will be 288 (0.90 ha). Trees will be top-worked in 2003.

Low-budded- The low-budded high density trial includes Gisela 6, Gi196-4, MxM14 and Mazzard rootstocks. The training systems included in this trial are 1) free standing, multiple leader, 2) free standing, central leader trees, and 3) a single wire trellis, central leader tree. This second planting will be planted at 10' x 16'. The total number of trees planted would be 324 trees (0.50 ha).

3. Continue to identify and secure for evaluation potential new, late ripening, self-fertile selections suitable for the processing cherry industry and potential fresh market in the Willamette Valley.

4. Continue to evaluate rootstock and cherry cultivars for *Pseudomonas* tolerance. We intend to continue screening the dark and blush cherry genotypes in the cultivar trials using a leaf and bloom assays.

5. Train, maintain and obtain data on yield, fruit size, tree vigor and other relevant data from the existing cherry rootstock trials which include:

   1995 Giessen rootstock trial (0.25 ha of top-worked 'Royal Ann' trees)

   1998 NC-140 cherry rootstock trial (0.50 ha low-budded central leader 'Bing')

   1998 Weiroot rootstock trial (0.20 ha of top-worked 'Sweetheart')

   2002 PiKu 1 and 3 trial (0.20 ha low-budded trees)

6. Evaluate growth and fruiting of 'Sweetheart' trees in the interstem trial which contains: low-grafted MxM 60, high-grafted MxM 60, low-grafted Gisela 5, high-grafted Gisela 5, Gisela 5 interstem with MxM 60 rootstock, MxM 60 interstem with Gisela 5 rootstock (0.10 ha).

7. Prune and train the MxM rootstock trial that were planted in fall 2001 and top-worked in spring of 2003 with 'Sweetheart'. (0.12 ha).

8. Evaluate a branch angle trial with 'Regina' on Mazzard. Four replicate trees that are being trained to central leader trees have the primary scaffolds trained to one of four branch angles (30°, 45°, 60° and 90° from the vertical central leader.) Yield and fruit quality data from the scaffolds will be obtained (0.05 ha).

9. Evaluate the response of burning on bud-break, shoot growth, branch angle and the presence of bacterial canker (0.05 ha).

10. Apply two plant growth regulators and a reflective mulch to determine their influence on cherry bloom delay or enhancement, and subsequent maturity and quality of fresh cherry fruit. The bloom enhancement chemical will be applied to late blooming 'Regina' trees. The bloom delay compound will be applied to 'Sweetheart'. The reflective mulch will be applied at two times, after bloom and 2-3 weeks before harvest.

11. Apply Retain to two cultivars, 'Sylvia' and 13S21-01 that have fresh market potential in the Willamette Valley and the region. The influence on stem pull force and fruit maturity and quality will be assessed. If a grower cooperator can be found, a Retain study on 'Skeena will also be implemented.

Summary of trials and land use:

Trial	Land use (ha)
1995 Gisela rootstock trial (‘Royal Ann’)	0.25
1996 BC dark cherry trial	0.15
1998 Blush cherry trial	0.35
1998 NC-140 cherry rootstock trial (‘Bing’)	0.50
1998 Weiroot rootstock trial (‘Sweetheart’)	0.20
1999 Interstem trial (MxM60, Gi5, and ‘Royal Ann’)	0.10
2000 MxM rootstock trial (‘Sweetheart’)	0.12
2001 Sweet cherry system/cultivar trial (top-worked)	0.90
2002 Sweet cherry system/cultivar trial (low-budded)	0.50
2002 PiKu trial	0.20
	3.27

Results and Discussion:

1996 Dark cherry cultivar trial (Table 1)- This trial consists of ‘Regina’, ‘Bing’ and 17 selections/cultivars from Dr. Frank Kappel’s Agriculture Canada cherry breeding program. Three trees per genotype are grafted onto Mazzard rootstock and trained to a central leader training system. Three additional selections were planted in 1997. A similar planting is located at a grower site owned and managed by Mr. Don Nusom. Trees have attained the desired height and have filled their allotted space. No gibberellin applications have been made so as to evaluate the genetic potential of each cultivar and selection. ‘Symphony’, ‘Newstar’, ‘Bing’, ‘Sonata’, 8S 03-13, 13S 49-24 began blooming the earliest in the trial, on 2-4 April, while the latest blooming genotypes included ‘Regina’, ‘Sandra Rose’, ‘Sylvia’, 13S42-49, and ‘Skeena’. Tree vigor and productivity are highly variable across genotypes. The selections that remain very promising are 13S49-24, 13S16-29 and ‘Staccato’. The cherry quality of ‘Sandra Rose’ and 13S 16-29 are very good however yields were low this year. ‘Sylvia’, ‘Regina’, ‘Skeena’, ‘Symphony’ and 13S 21-01 also have very desirable traits for the fresh market. Fruit size was a bit small for ‘Regina’. ‘Skeena’, ‘Symphony’ and 13S 21-01 had stem pull forces below 500g, which may be of concern with respect to stem retention but may be an advantage for stemless cherry production systems. The soluble solids concentration (SSC) of ‘Sylvia’ fruit was relatively low in comparison to most of the other genotypes in the trial.

1998 Blush cherry trial (Table 2)- The trial was planted on 21 April 1998 and consists of 9 selections from Cornell University, NY; 8 BC selections; ‘Royal Ann’ and ‘Sweetheart’. All genotypes were low-budded onto Gisela 5 rootstock. Six replicate trees are planted for each genotype. Trees are being trained as a central leader. Cherries are being evaluated for their suitability for both the brine industry and potential fresh market production. Peak bloom dates were separated by 12 days and spanned from 10-22 April. Yields ranged from 1.1-13.6 kg/tree. Fruit size ranged from 22-30mm. The most promising selections this year that may be suitable for the brine industry include NY252, NY8182, NY9295, 13N 07-39, ‘Sweetheart’, and ‘Stardust’. Larger fruited selections when grown on Gisela 5 that may have fresh market potential include NY307, 13N 07-39, 13N 07-32, and 2N 31-19.

1998 NC-140 ‘Bing’ rootstock trial (Table 3)- Eight replicate trees each of ‘Bing’, grown on seven Giessen and six Weiroot selections, Edabriz, Mahaleb, and Mazzard rootstocks, were planted 21 April 1998. The trees were planted at a 12’ x 16’ spacing and are being trained to a central leader.

Suckering is high on Gisela 4, Gisela 7, W13, W154, and W10. First bloom was spread over a period of 3 days. The most productive rootstocks were Gi 209-1, W72, Gisela 5, and Gisela 7. The least productive were Mahaleb, W154, Mazzard, W158, W10, W13, 'Edabriz' and Gi 318-17. Fruit size ranged from 26.8mm from trees on Mazzard rootstock to 27.8mm from trees on W158 rootstock. Fruit cracking in this trial ranged from 0-30% and rootstock had a significant effect.

Bacterial canker tolerance(Table 4)- The aforementioned trials were evaluated for field incidence of bacterial canker-like symptoms. 'Staccato', 13N 14-22, and 'Cristalina' developed the most symptoms of the dark cherries. In the blush trial, genotypes that exhibited no symptoms included; 'Stardust', NY13688, 13N 07-39, and NY8182. Rootstock has influenced the development of symptoms in the NC140 trial. 'Bing' trees grafted onto Gisela 4, Gi195-20, Gisela 6, Gisela 5, and 'Edabriz' rootstocks have the highest number of infected scaffolds.

1995 Gisela rootstock trial (Table 5)- Eight replicate trees each of Gisela 1, 5, 6, 7, 8 and 11 were planted in 1995. In 1997 and 1998, rootstocks were top-worked with two bud grafts of 'Royal Ann'. 'Sweetheart' was top-worked onto F12/1 in 1998 as a pollinizer. Trees were mechanically harvested with a limb shaker in 2002. Mazzard and Gisela 1 had the lowest yields in 2002. Gisela 5 and 7 trees produced the highest and similar yields. The trunk-cross sectional area of Mazzard was more than twice as large as Gisela 1 to 5+ times greater than Gisela 6. Fruit size was largest on Gisela 1 and smallest on Gisela 5. Gisela 6, 8 and Mazzard had the highest number of suckers. Stem pull force was lowest on Mazzard rootstock but fruit were more mature. However, Gisela 8 had similar SSC (similar maturity) yet stem pull force was significantly higher. Rootstock again influenced stem pull force.

1998 Weiroot rootstock trial (Table 6)- The Weiroot rootstocks; 10, 13, 53, 154, and 158, had 3-5 major scaffolds top-worked at ~1.0 m with 'Sweetheart' scionwood in May 2000. Gi5 and Mazzard were planted as controls. 'Sweetheart' trees bore their first significant crop in 2002. W13 trees produced 6-9 times more fruit than W53, W154, and W158 trees. Fruit size and firmness were excellent. Fruit harvested from W158 had the greatest incidence of cracking. Stem pull force was significantly lower for fruit harvested from Mazzard and W53 trees, although the force was above 700 g. W154 produced the greatest number of suckers.

2000 MxM rootstock trial- The MxM rootstocks; 2, 14, 39, 46, and 60 were planted at an 18' x 18' spacing during Fall 2000. Rootstocks were top-worked with 'Sweetheart' in spring 2002.

2001 Sweet cherry systems/cultivar trial-
Higher density planting: Gisela 6, Gi196-4 and Maxma14 were low-budded with 'Sweetheart', 'Stardust', and 'Royal Ann' in September 2001 by Columbia Basin Nursery. Trees will be dug and planted in mid-November 2002.
Low-density top-worked planting: Rootstocks of Gi 196-4, Maxma14, MxM60 and Mazzard seedling were planted in spring 2002 and have grown well. The rootstocks will be top-worked in spring 2003 with 'Royal Ann' 'Sweetheart' and 'Stardust',

2002 PiKu trial- Ten cultivars, 'Sweetheart', 'White Gold', 'Sonata', 'Royal Ann', Skeena', 'Lapins', 'Regina', 'Black Gold', 'Attika' and 'Bing' are being evaluated on PiKu 1 and 3. Four tree replicates were planted for each combination in spring 2002.

1999 Interstem trial (Table 7)- The interstem trial was planted in September 1999. The trial consists of Gisela 5 and MxM60 rootstocks which were either grafted high (~75cm) or low (~15 cm) with 'Royal Ann', or the rootstocks were used as reciprocal interstems. MxM60 low- or high-grafted trees had the largest TCSA. Low–grafted Gisela 5, regardless of trunk genotype (MxM60 or Royal Ann),

were intermediate in TCSA. The smallest TCSA's were found with trees where Gisela 5 is the trunk (interstem or high grafted). Gisela 5 as the rootstock induced earlier flowering in 'Royal Ann' relative to the MxM60 rootstock.

2001 'Lapins' notching trial (Table 8)- Notches were cut above four buds on the central of leaders of 3 year old 'Lapins' trees that were grafted onto Gisela 6 rootstocks. Leaders were notched dormant, green tip, green tip + 1 week, green tip + 2 weeks and green tip + 3 weeks to determine the effect on shoot length, budbreak, and branch angle. After green tip + 1 week, there was a decline in the number of buds that broke. Mean shoot length and shoot angle were not affected by treatment. Some gumming was observed at the site of the notching.

2001 'Lapins' disbudding/shoot removal trial (Table 9)- Four to five buds or shoots were removed from the apical most portion of the central leader leaving the terminal bud intact. Treatments were applied dormant, green tip, green tip + 1 week, green tip + 2 weeks and green tip + 3 weeks. Disbudding was not effective this year in inducing branching on the leader of 3-yr old 'Lapins' trees.

2002 'Sweetheart' leader burning trial (Table 10)- A preliminary study was begun with a soldering iron to burn the central leader above three to four buds at green-tip + 2 weeks to determine the influence on bud break, shoot angle and shoot length. The treatments included a wide burn, one narrow burn and 3 narrow burns. All burn treatments produced a similar result and no gumming was observed at the site of the burns. Shoots in untreated trees originated only from the buds subtending the terminal bud. No shoots were found below the terminal portion of the one-year wood.

2000 'Regina' branch angle trial (Table 11)- 'Regina' trees grafted onto Mazzard rootstock that were planted in 1999 are being used in this trial. Four replicate trees received one of four branch angle treatments; 30°, 45°, 60° and 90° from the vertical central leader. Three to four scaffolds per tree were trained to these angles. Cluster no. tended to decrease as angle decreased. Yields were significantly higher on trees where branches were trained to horizontal. Cluster density decreased as branch angle decreased. Training 'Regina' trees to 60-90° from the leader will induce heavier flowering and cropping.

1998 Budding height trial- 'Royal Ann' was budded onto Gisela 5 at 3 different heights- 12", 24", and 36". Trees have completed their third growing season. The overgrowth of the graft union increases as the budding height increases. This plot has been removed because of tree losses from bacterial canker and inadequate replication.

Sweet cherry fruit growth curves- During the 2001 and 2002 growing seasons, fruit diameter measurements were taken for eight genotypes that matured over a range of ripening times. The cultivars included 'Bing', 'Cristalina', 'Regina', 'Sandra Rose', 'Sonata', 'Staccato', 'Sweetheart' and 'Symphony. Growth curves were evaluated by calendar date and growing degree-days. Transition points in the double sigmoidal growth curves and slopes of the lines during the three growth phases were determined. The different maturity times of cherry cultivars are influenced by the duration of the pit hardening stage and the rate of growth during final swell. This information will assist orchardists in better targeting the GA sprays that are used to improve fruit quality.

Table 1. Harvest and bloom dates, yield, trunk cross-sectional area, yield efficiency, fruit size, firmness, soluble solids, pH, fruit color, cracking, pull-force, and stem weight of cultivars and Agriculture Canada selections grafted onto Mazzard rootstock and planted in 1996. Highlighted genotypes have been identified as having desirable traits for the fresh market.

Genotype[z]	Harvest date	First bloom	Peak bloom	Yield (kg)	TCSA[x] (cm^2)	Yield efficiency (kg/ cm^2)	Fruit size (mm)	Row-size	Firmness (g/mm^2)	SSC[w] (^oBrix)	pH[w]	Fruit Color (1-7)	Cracking (%)[t]	Pull force (g)	Stem Wt. (g)
Newstar	June 27	April 3	April 10	9.9	169	.06	26.5	10.2	247[s]	21.3	3.6	5.5	46.0	959	n/a
Sandra Rose	June 27	April 11	April 19	3.7	188	.02	26.7	10.1	280[s]	20.9	3.3	5.3	0.0	840	n/a
Cristalina	July 1	April 6	April 18	7.7	108	.07	26.3	10.5	281	17.4	3.8	5.4	12.3	450	3.0
Bing[v]	July 2	April 4	April 12	2.4	127	.03	27.1	10.1	278	21.9	3.5	5.3	28.0	758	2.4
8S 03-13	July 2	April 4	April 11	3.4	149	.02	29.2	9.4	249	20.2	3.3	5.8	30.0	658	3.3
Sonata	July 3	April 4	April 10	5.8	126	.05	29.2	9.4	327	18.7	3.2	5.3	41.3	696	4.0
Sylvia	July 3	April 11	April 20	12.0	180	.12	27.9	9.9	266	16.2	3.7	4.5	5.3	620	3.3
13S 21-07	July 7	April 6	April 13	8.3	114	.05	27.8	9.9	389	20.8	3.4	5.3	20.4	594	2.5
13S 49-24	July 7	April 4	April 12	14.9	150	.10	28.4	9.7	258	19.8	3.2	5.4	26.8	627	2.9
13S 17-40	July 7	April 6	April 14	18.0	132	.14	26.1	10.5	221	19.0	3.3	5.9	12.9	484	2.7
13S 18-15	July 7	April 5	April 11	7.6	84	.13	28.1	9.9	217	18.4	3.6	5.7	35.6	581	2.5
13S 42-49	July 7	April 12	April 18	10.2	124	.08	27.5	10.0	373	17.7	3.2	5.3	34.0	630	3.3
Regina[v]	July 10	April 10	April 21	7.6	92	.08	25.7	10.6	282	21.1	3.5	5.9	0.0	751	2.8
13S 16-29[v]	July 15	April	April	2.7	123	.02	26.9	10.2	326	22.9	3.2	5.0	0.0	632	2.6

Skeena[u]	July 16	8 April	15 April	n/a	n/a	n/a	28.6	9.7	307	20.4	3.5	n/a	0.0	476	2.3
Symphony	July 18	12 April	19 April	10.2	179	.06	27.6	10.0	305	20.5	3.6	4.9	19.1	496	3.0
Staccato[v]	July 18	2 April	12 April	2.8	143	.02	26.9	10.2	356	22.5	3.4	4.6	2.8	791	2.6
4W 11-08	July 23	5 April	14 April	3.8	144	.03	29.1	9.5	235	21.7	3.5	5.4	44.0	476	3.8
13S 21-01	July 23	7 April	17 April	16.9	114	.15	26.7	10.2	390	19.9	3.2	4.8	4.0	496	3.1
13N 14-22	n/a	6 April	15 April	n/a	110	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
MSD		2.4 days	1.5 days	5.1	69	.03	0.4	0.2	17	2.4	0.1	0.3	12.1	41	0.6
Selection criteria								10.5	225	18			28	600	

[z]Means separation by Waller-Duncan k-ratio t-test, k-ratio = 100. MSD=Mean significant difference.
[x]TCSA=trunk cross-sectional area in September 2002.
[w]Composite sample of 25 fruit.
[v]Planted one year later.
[u]Based on 25 fruit from grafted trees.
[t]Fruits with one or more cracks.
[s]Firmness measurements were made 2 weeks after harvest.

Table 2. Harvest and bloom dates, yield, trunk cross-sectional area, yield efficiency (YE), soluble solids (SSC), pH, firmness, fruit size, cracking, pull force and stem weight of cultivars and blush selections grafted onto Gisela 5 rootstock and planted in 1998. Highlighted genotypes have been identified as promising brine cherry selections.

Genotype[z]	First bloom	Peak bloom	Harvest date	Yield (kg)	TCSA[y] (cm^2)	YE (kg/cm^2)	SSC[w] (^oBrix)	pH	Firmness (g/mm^2)	Fruit size (mm)	Row-size	Cracking (%)	Pull force (g)	Stem wt.[w] (g)
NY518[v]	April 2	April 13	July 1	3.7	71.4	.05	n/a	n/a	431	23.6	11.6	n/a	922	n/a
Royal Ann[v]	April 6	April 16	July 1	11.9	82.2	.15	n/a	n/a	234	22.1	12.3	n/a	830	n/a
NY252	April 3	April 12	July 2	5.5	71.0	.08	17.6	3.3	331	25.9	10.6	4.8	1006	2.4
NY7690	April 3	April 12	July 2	1.1	85.0	.01	21.9	3.5	352	30.3	9.1	28.5	780	2.8
NY6091	April 6	April 13	July 2	2.9	77.1	.04	19.9	3.6	237	27.8	9.9	6.1	649	4.0
NY8182	April 6	April 14	July 2	11.6	65.6	.18	17.0	3.8	307	24.5	11.1	9.3	899	2.5
NY13688	April 9	April 20	July 2	12.3	55.1	.22	16.8	3.6	213	24.3	11.2	17.3	680	2.4
NY9295	April 10	April 21	July 2	10.3	73.7	.14	17.7	3.3	376	25.6	10.7	4.7	855	3.3
NY7855	April 11	April 21	July 2	7.3	63.5	.12	19.1	3.5	258	24.1	11.5	0.0	480	3.2
NY307	April 12	April 21	July 3	4.1	77.4	.05	18.4	3.5	249	27.7	9.9	4.7	639	3.7
13S 20-11	April 6	April 14	July 8	1.5	61.2	.02	16.8	3.6	422	25.0	11.0	0.0	1165	3.2
13N 07-39	April 6	April 14	July 8	13.6	78.6	.17	18.0	3.5	341	27.0	10.2	8.1	1074	2.6
13S 07-50	April 17	April 18	July 8	3.1	44.5	.07	21.6	3.6	215	27.1	10.1	18.1	466	3.6
13N 07-32	April 12	April 21	July 8	6.8	62.7	.11	19.0	3.4	228	29.1	9.5	10.1	652	3.7
Sweetheart	April 5	April 14	July 12	4.2	67.7	.06	19.7	3.5	346	26.9	10.2	1.3	965	2.8
13S 21-14	April 5	April 12	July 12	5.6	47.6	.12	14.5	6.5	n/a	n/a	n/a	0.0	n/a	2.9
13S 09-37	April 11	April 22	July 12	11.6	70.5	.16	19.0	3.6	280	25.1	10.9	13.2	511	2.3
Stardust	April 10	April 21	July 15	9.6	61.0	.16	19.8	3.9	256	25.7	10.7	1.0	639	2.4
2N 31-19	April 3	April 10	July 19	7.4	57.5	.12	17.8	3.3	235	27.1	10.1	4.0	605	3.0
MSD	<1 day	1.1 days		2.5	9.0	.04	1.7	2.4	29	1.2	0.5	17.5	113	0.5
Selection criteria				4.0					225	27			600	

[z]Means separation by Waller-Duncan k-ratio t-test, k-ratio = 100.
[y]TCSA = trunk cross-sectional area in September 2002.
[w]Composite sample of 25 fruit.
[x]Mean of 25 fruit.

[v]Evaluated at 2+ weeks storage.

Table 3. Bloom dates, yield, trunk cross-sectional area, yield efficiency (YE), fruit weight, soluble solids concentration (SSC), fruit cracking, pull force, and suckering of 'Bing' trees planted in the 1998 NC-140 rootstock trial at the Lewis-Brown Research Farm, Corvallis, OR. Fruit were harvested on 2 July 2001. Highlighted rootstocks are those that are commercially available.

Rootstock[z]	First bloom	Peak bloom	Yield (kg)	TCSA[y] (cm^2)	YE (kg/cm^2)	Firmness (g/mm^2)	Fruit size (mm)	Row-size	SSC[w] (^oBrix)	pH[w]	Fruit color (1-7)	Cracking (%)	Pull force (g)	Stem wt.[w] (g)	Sucker rating[x] (0-4)
Gi 209-1	April 4	April 15	6.5	68	.10	303	27.1	10.1	19.2	3.7	4.6	20.6	872	2.6	0.0
W 72	April 5	April 15	5.4	74	.08	315	27.2	10.1	19.3	3.5	4.6	30.0	877	2.3	1.1
Gi 5 (148-2)	April 5	April 15	5.1	87	.06	340	27.2	10.0	19.9	3.5	4.2	16.0	862	2.9	0.0
Gi 7 (148-8)	April 4	April 14	4.8	80	.06	344	27.5	10.0	20.3	3.6	4.7	15.0	1073	2.5	3.0
Gi 6 (148-1)	April 5	April 15	4.1	127	.03	316	27.5	10.0	19.5	3.5	4.2	25.5	902	2.8	0.0
Gi 195-20	April 5	April 14	3.7	105	.03	336	27.5	10.0	20.6	3.7	4.7	26.5	944	2.6	0.3
W 53	April 5	April 15	3.5	65	.05	334	28.1	9.8	21.5	3.6	5.0	0.0	890	2.6	0.9
Gi 4 (473-10)	April 6	April 12	3.5	68	.03	n/a	n/a	n/a	18.2	3.6	4.1	28.6	826	2.5	3.0
Gi 318-17	April 6	April 14	2.4	105	.03	329	27.5	10.0	20.2	3.6	4.5	18.3	942	2.2	0.0
Edabriz	April 5	April 14	2.1	88	.03	326	27.7	9.9	19.9	3.5	4.6	18.8	938	2.0	0.6
W 13	April 5	April 13	1.8	123	.02	304	27.6	10.0	20.3	3.6	4.6	13.1	899	2.1	2.3
W 10	April 5	April 14	1.6	122	.01	317	27.4	10.0	20.5	3.5	4.9	20.0	867	2.1	1.6
W 158	April 5	April 14	1.5	110	.01	333	27.8	9.9	21.8	3.6	5.3	22.5	963	2.4	0.8
Mazzard	April 5	April 13	1.1	132	.01	310	26.8	10.2	20.7	3.6	4.8	22.4	782	1.8	0.9
W 154	April 5	April 12	0.9	102	.01	312	27.7	9.9	20.2	3.5	4.8	30.3	932	2.2	2.6
Mahaleb	April 7	April 14	0.6	106	<.01	288	27.5	10.0	20.2	3.6	4.9	25.6	816	1.7	0.9
MSD	1.7 days	1.4 days	2.1	18	.03	13	0.3	0.1	1.4	0.1	0.3	8.4	36	0.4	0.7

[z]Means separation by Waller-Duncan k-ratio t-test, k-ratio = 100.
[y]TCSA = trunk cross-sectional area in September 2002.
[x]Sucker rating: 0 = no suckers, 1 = 1-10 suckers, 2 = 11-20 suckers, 3 = 21-30 suckers, 4=30+.
[w]Composite sample of 25 fruit.
[v]Evaluated at 2+ weeks storage.

Table 4. Mean number of scaffolds that have bacterial canker-like symptoms in the dark, blush and NC140 sweet cherry trials.

Genotype[z]	n	Scaffold no.	Genotype[z]	n	Scaffold no.	Genotype[z]	n	Scaffold no.
Staccato[v]	3	3.0	NY6091	6	2.2	Gi 4 (473-10)	1	3.0
13N 14-22	3	3.0	NY7690	6	1.7			
Cristalina	4	1.8	13S 07-50	6	1.5	Gi 195-20	8	2.5
13S 21-07	5	0.6	13S 21-14	6	1.0	Gi 6 (148-1)	8	2.5
13S 49-24	3	0.3	NY9295	6	1.0			
Newstar	2	0.0	Royal Ann[v]	6	0.8	Gi 5 (148-2)	8	2.4
Sandra Rose	3	0.0	NY252	6	0.7			
			2N 31-19	6	0.7	Edabriz	8	2.1
Bing[v]	4	0.0	Sweetheart	6	0.7	W 53	8	1.9
8S 03-13	2	0.0	13S 20-11	6	0.7	Gi 7 (148-8)	8	1.9
Sonata	3	0.0	NY7855	6	0.7			
Sylvia	3	0.0	NY518[v]	6	0.5	Gi 318-17	8	1.9
13S 17-40	4	0.0	13N 07-32	6	0.3	Gi 209-1	8	1.4
13S 18-15	3	0.0	NY307	6	0.2	W 10	7	1.3
13S 42-49	2	0.0	13S 09-37	5	0.2	W 154	5	1.2
Regina[v]	2	0.0	NY8182	6	0.0	W 158	8	1.2
Symphony	2	0.0	13N 07-39	6	0.0	Mahaleb	8	1.1
4W 11-08	3	0.0	NY13688	6	0.0	W 13	7	1.1
13S 21-01	2	0.0	Stardust	6	0.0	W 72	7	1.0
Skeena[u]	1	0.0	MSD		1.3	Mazzard	8	0.5
MSD		1.0				MSD		1.5

[z]Means separation by Waller-Duncan k-ratio t-test, k-ratio = 100.

Table 5. Influence of Gisela rootstocks on bloom time, yield, trunk cross-sectional area, yield efficiency, fruit weight, soluble solids concentration (SSC), pull force, and suckering of top-worked 'Royal Ann' trees.

Highlighted rootstocks are those that are commercially available.

Rootstock[z]	First bloom	Peak bloom	Yield (kg)	TCSA[y] (cm^2)	Yield efficiency (kg/cm^2)	Fruit weight (g)	SSC (^oBrix)	Pull force (g)	Sucker rating[x] (0-4)
Gisela 1 (172-9)	April 5	April 14	6.2	157	.05	7.8	18.4	730	0.3
Gisela 11(195-1)	April 5	April 14	14.4	85	.17	7.1	18.1	735	0.1
Mazzard	April 4	April 14	7.8	346	.02	6.9	19.2	573	1.5
Gisela 5 (148-2)	April 5	April 14	21.9	77	.29	6.4	17.5	734	0.4
Gisela 7 (148-8)	April 5	April 15	21.3	75	.28	6.8	17.8	718	0.5
Gisela 6 (148-1)	April 5	April 13	12.1	63	.19	7.3	17.9	754	3.1
Gisela 8 (148-9)	April 4	April 13	11.8	69	.18	7.3	18.9	701	2.4
MSD	1.7 days	< 1 day	4.5	31	.05	0.6	1.1	65.2	0.5

[z]Means separation by Waller-Duncan k-ratio t-test, k-ratio = 100.
[y]TCSA = trunk cross-sectional area in September 2002.
[x]Sucker rating: 0 = no suckers, 1 = 1-10 suckers, 2 = 11-20 suckers, 3 = 21-30 suckers, 4 = 30+.

Table 6. The influence of top-worked Weiroot rootstocks on the yield, TCSA, change in TCSA, yield efficiency, fruit size, rowsize, soluble solids concentration (SSC), pH, fruit color, percent cracking, stem removal force and suckering of 'Sweetheart' trees. Trees were top-worked in spring 2000.

Rootstock[z]	Yield (kg)	TCSA[y] (cm^2)	Yield efficiency (kg/cm^2)	Firmness (g/mm^2)	Fruit size (mm)	Row-size	SSC[w] (^oBrix)	pH	Fruit color (1-7)	Cracking (%)	Pull force (g)	Sucker rating[x] (0-4)
W53	0.4	13	.05	353	28.2	9.8	21.5	3.5	4.6	14	710	0.6
W154	0.7	19	.04	358	28.5	9.7	21.9	3.4	4.4	16	865	1.1
W158	0.6	48	.01	353	28.7	9.6	21.2	3.3	4.7	23	933	0.7
Gi 5	2.5	45	.06	348	28.9	9.5	21.1	3.4	4.4	9	940	0.2
W10	2.3	54	.04	352	28.1	9.8	20.2	3.4	4.2	10	907	0.8
W13	3.6	58	.06	359	28.2	9.7	20.2	3.4	3.8	3	971	0.6
Mazzard	2.0	155	.01	342	28.1	9.8	19.3	3.4	4.1	8	737	0.4
MSD	0.8	11	.02	17	0.3	0.1	1.0	0.1	0.4	7	36	0.4

[z]Means separation by Waller-Duncan k-ratio t-test, k-ratio = 100.
[y]TCSA = trunk cross-sectional area in September 2002.
[x]Sucker rating: 0 = no suckers, 1 = 1-10 suckers, 2 = 11-20 suckers, 3 = 21-30 suckers, 4 = 30+.
[w]Composite sample of 25 fruit.

Table 7. The influence of the grafting height and interstems of MxM60 and Gisela 5 on bloom and trunk cross-sectional area. Trees were planted in spring 2000. Highlighted cells draw your attention to the overgrowth of the graft union above the interstem or high-grafted union.

Grafting height and interstem combination	First bloom	Peak bloom	TCSA at 30 cm (cm^2)	TCSA at 10 cm above interstem/ rootstock (cm^2)	TCSA at 10 cm below interstem/ rootstock (cm^2)
MXM60 interstem/Gi 5 rootstock	Apr 3	Apr 10	33.8	29.3	29.3
High grafted Gi 5	Apr 5	Apr 12	25.6	37.4	-
High-grafted MXM60 rootstock	Apr 4	Apr 12	49.5	49.3	-
Low-grafted MXM60 rootstock	Apr 6	Apr 13	46.6	-	62.4
Gi 5 interstem/MXM60 rootstock	Apr 5	Apr 12	24.4	38.6	47.0
Low-grafted Gi 5	Apr 4	Apr 11	33.2	-	32.9
MSD	1.9 days	1.9 days	8.4	8.3	11.0

[z]Means separation by Waller-Duncan k-ratio t-test, k-ratio = 100.

Table 8. The influence of time of notching on shoot length, angle and branch number from the central leader of 'Lapins' cherry trees that are grafted onto Gisela 5 rootstock. Four notches were made on each leader.

Notching date	Shoot length[z] (cm)	Shoot angle (°)	Shoots (% of notched buds)
Dormant	50.5	53.5	63
Green tip	46.1	64.3	88
Green tip + 1 week	53.1	55.0	50
Green tip + 2 weeks	22.3	56.7	19
Green tip + 3 weeks	44.7	65.0	0
MSD	ns	ns	37

[z]Means separation by Waller-Duncan k-ratio t-test, k-ratio = 100, ns=nonsignificant.

Table 9. The influence of the time of disbudding or shoot removal in 2002 on shoot length, angle, and percent shoots from the central leader of 'Lapins' trees grafted onto Gisela 5 rootstocks.

Disbudding/shoot removal date	Shoot length[z] (cm)	Shoot angle (º)	Shoots (% of sites)
Dormant	2.8	75.0	13
Green tip	41.0	60.0	13
Green tip + 1 week	3.0	60.0	6
Green tip + 2 weeks	0.0	n/a	0
Green tip + 3 weeks	0.0	n/a	0
MSD	ns	ns	ns

[z]Means separation by Waller-Duncan k-ratio t-test, k-ratio = 100, ns=nonsignificant.

Table 10. The influence of the time of burning at Green tip+2 weeks in 2002 on shoot length, angle, and percent shoots on 3-4 one-year old laterals of 'Sweetheart' trees grafted onto Gisela 5 rootstocks.

Burn type	Shoot length[z] (cm)	Shoot angle[z] (º)	Shoots (% of sites)
Wide burn	46.1	52.7	65
1 narrow burn	32.4	48.8	56
3 narrow burns	36.9	62.0	39
MSD	ns	ns	ns

[z]Means separation by Waller-Duncan k-ratio t-test, k-ratio = 100, ns=nonsignificant.

Table 11. Bloom dates, cluster number per scaffold and yield of 'Regina' trees where primary scaffolds were trained to a range of different branch angles.

Branch angle from leader	First bloom	Peak bloom	Cluster no.	Bloom density (no./cm^2)[y]	Yield (g)
90	April 13	April 25	25.0	2.1	1093.0
60	April 14	April 25	21.6	1.7	417.2
45	April 15	April 26	17.5	1.2	107.6
30	April 15	April 25	21.0	1.5	561.4
MSD	ns	ns	5.5	0.5	530.4

[z]Means separation by Waller-Duncan k-ratio t-test, k-ratio = 100, ns=nonsignificant.
[y]Bloom density= cluster no./branch cross sectional area (cm^2).

Budget

Proposed Title: Horticulture management systems for high value fresh and brine cherries
Project Leader: Anita Nina Azarenko
Project duration: Indefinite
Current year: 2003
Previous year funding: $33,475
Current year request: $46,000

Current year breakdown:

ITEM	2002	2003
Salaries	$13,656	**$22,500**
Benefits (54%)	7,374	**11,700**
Wages	3,900	**4,420**
Benefits (5%)	195	**221**
Plot charges	5886	**6,213**
Equipment	2000	
Supplies		**446**
Travel	464	**500**
Total	$33,475	**$46,000**

CONTINUING PROJECT PROPOSAL **YEAR 3/3**
WTFRC Project #CH-01-03

Project title: Nitrogen partitioning in cherry

Principal investigator: Anita Nina Azarenko
Organization: Dept. of Horticulture, Oregon State University, 4017 ALS, Corvallis, OR 97331-7304
Research assistant: Annie Chozinski, Department of Horticulture, Oregon State University

Cooperators: Tim Righetti, Department of Horticulture, Oregon State University
Lynn Long, Wasco Cty Extension, OSU
John Carter, The Dalles, OR

Objectives
1. To determine the effect of the timing of N fertilizer application on uptake and partitioning of N in sweet cherries.
2. To estimate the contribution of mineralized, fertilizer and recycled N to cherry tree growth.
3. To develop N management strategies that consider the physiology of N uptake in the tree and optimize N uptake from the soil.

Significant Findings
Nitrogen uptake efficiency declines significantly during the growing season. In spring, uptake efficiency in cherry was similar to that of other fruit crops, ~20%. In the autumn, uptake efficiency decreased to 4%. Urea uptake efficiency was 24%.

Methods:
Under objective 1. Four N treatments were applied to the soil around the base of four replicated, mature, bearing cherry trees. The dates of application were May 10, June 8, August 3 and September 26, 2001. Labeled nitrogen (^{15}N) in the form of ammonium sulfate fertilizer was applied to the soil at 40 lb/A of N. A post-harvest foliar urea application (5%) was applied in the beginning of October at 100 gal/A rate. Fruit yields were obtained and then sampled for total N and ^{15}N content in 2001 and 2002. Shoot and spur leaves were sampled at the end of July. One set of trees (20 trees) was excavated at the end of October 2001, partitioned, and analyzed for total N and ^{15}N content. Efficiency of uptake will be calculated as well as N and dry matter partitioning. The remaining set of 20 trees was harvested, leaves sampled and trees dug and partitioned in October 2002. Again, N content and ^{15}N distribution will be determined. Data will be evaluated and summarized for the amount of N remobilized from reserves.

In Spring 2003, labeled nitrogen (^{15}N) in the form of ammonium sulfate will be applied before budbreak and then at bloom to four replicate bearing trees. Additionally, four newly planted trees will receive ^{15}N labeled fertilizer in the spring over the next five years to develop N budgets and assess N uptake efficiency of young trees. Four trees will be removed each year for five years and divided into components. N distribution and uptake efficiency will also be determined.

Under objective 2. The following treatment combinations had been applied to four trees each by mid-summer 2002.

2001	2002
Spring application	
Labeled N	Unlabeled N
Labeled N	No fertilizer
Unlabeled N	Label
Unlabeled N	No fertilizer
Post-harvest application	
Labeled N	Unlabeled N
Labeled N	No fertilizer
Unlabeled N	Label
Unlabeled N	No fertilizer

Trees were harvested, leaf samples taken, fruit and leaves analyzed for total N and ^{15}N concentration in 2001 and 2002. In October 2002, the 32 trees were dug, partitioned, weighed, sub-sampled. Samples will be analyzed for total N and ^{15}N concentration. Again, total N content and ^{15}N distribution will be determined. Data will be evaluated and summarized.

Under objective 3. Current N fertilizer recommendations will be re-evaluated. Recommendations and extension publications will be revised according to the research findings. The extension publication will be written in collaboration with Lynn Long and Tim Righetti. Results will be submitted for publication. The research results and interpretation of the data will also be posted on the Oregon's fruit and nut orchard network.

Results and discussion:

Under objective 1:

Uptake efficiency of N declines considerably from May until September from 21% to 4%. To optimize N uptake, fertilizers should be applied in the spring, taking into consideration previous season's crop load and vigor. Urea has a similar uptake efficiency as the spring applications and should be considered an important tool for late season N management.

Timing of N application in 2001	Total N (g/tree)	Total ^{15}N (g/tree)	Total N (lbs/A)	Total ^{15}N (lbs/A)	N derived from the fertilizer (%)	Uptake efficiency (%)
10 May	238	30	65	8.4	13.2	21
8 June	236	16	65	4.5	6.9	11
3 August	204	8.9	56	2.4	4.4	6
26 September	191	5.8	53	1.6	2.7	4
Urea- October	185	.08	51	.02	.04	24
MSD	ns	8.7	ns	2.4	2.9	10

Gratitude and recognition: We thank all of the growers in The Dalles who contributed their time, and financial and human resources. Without their support and commitment to this project, we would not have been able to accomplish this very time and labor-intensive study. Special thanks to Steve and Karen Rempel, Mel and Linda Omeg, John Carter,

Budget

Project title: Nitrogen partitioning in cherry
Principal investigator: Anita Nina Azarenko
Project duration: Completion 2003
Current year: 2003
Previous year funding: $10,300
Current year request: $7,500
Current year breakdown:

ITEM	2002	2003
Wages	$3,900	**3,900**
Benefits (5%)	195	**195**
Travel	405	**455**
Services and supplies		
Labeled ammonium sulfate	1,000	**250**
Sample analysis	4,800	**2,700**
Total	$10,300	**$7,500**

FINAL REPORT
WTFRC Project # CH-02-203 **WSU Project** #13J-3655-5346

Project title: New tactic for suppressing cracking of cherries
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Organization: Irrigated Agriculture Research & Extension Center, WSU-Prosser

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Objectives:

1. Determine efficacy of spraying a new formulation to repel water from cherries. The formulation will be hydrophobic (lipophilic) and contain an osmoregulator (e.g., calcium chloride).
2. Study timing and rates of application of the formulation.
3. Investigate fruit cracking under microscopes and determine the effect(s) of calcium and the hydrophobic formulation.
4. Determine whether fruit quality and appearance are altered by the formulation.

Significant findings:

These findings are divided into three categories:

I. Several factors were discovered to influence the rate and amount of cracking.
   A. Cherry cracking increased as air and fruit surface temperature increased. Surface temperatures of sun-exposed fruit in the field exceeded air temperature by as much as 10.2ºC (over 18ºF) (See Fig. 1).
   B. 'Bing' cherries immersed in deionized water (similar to rain water) held at 40ºC (104ºF), 30ºC (86ºF) or at 22ºC (72ºF) cracked far more quickly at 104ºF than at 72ºF (See Fig. 2).
   C. Water quality affected cherry cracking. Cracking was delayed in city water, irrigation water, and in sugar solution as compared to deionized water (Fig. 3). This is due to the higher salt concentration (and higher osmotic concentration) of these waters as compared to rainwater or deionized water.
   D. Water absorption by cherries also was most rapid when immersed in deionized water and was delayed in sugar solution and city water (Fig. 4).

II. Applying two new formulations (also called matrix) to cherries showed promise in suppressing cracking.
   A. One of the formulations applied at 10% or 20% (v/v) reduced water absorption when applied to cherries prior to immersion of cherries in deionized water (Fig. 5).
   B. One of the formulations also substantially reduced cracking of 'Bing' cherries immersed in deionized water for up to 9 hours (Fig. 6).
   C. One of the formulations reduced cracking and also delayed cracking of the stem bowl in 'Bing' cherries that were inverted and partially submerged at 30ºC (86ºF) and 45ºC (113ºF) (Fig. 7).
   D. Results obtained with the stem bowl in 'Rainier' cherries at 30ºC (86ºF) and 45ºC (113ºF) were similar to results cited in C above (Fig. 8).

E. In a field experiment with 'Bing' cherries, one formulation significantly reduced cracking from 29.6% in the control to 15.4% ($P<0.01$), and another formulation decreased cracking to 9.3% ($P<0.01$) (Fig. 9). However, formulation II provided a better appearance to the treated cherries than did the other.

III. The formulation also showed promised for reducing water loss from cherries post-harvest.
   A. Water loss from harvested 'Sweetheart' cherries was decreased by applying the formulation immediately after harvesting fruit either with or without the pedicel (stem) attached to the fruit (Fig. 10).
   B. We observed better retention of green stems (pedicels) on the cherries to which the formulation was applied, except in one experiment with 'Sweetheart' cherries.

Methods:
The methods described below are organized to correspond to each figure presented in the Results and Discussion section.

Fig. 1—*Air temperature vs. cherry fruit surface temperature*—Thermocouples connected to a Campbell Scientific CR10X data logger were attached to 'Sweetheart' cherries to record fruit surface temperature on the southwest side of fruit (full sun exposure in afternoon) throughout the day at 5-minutes intervals. A thermocouple placed in the shade recorded air temperature. This study was conducted 3 weeks before fruit maturity on 'Sweetheart' cherries in a Wenatchee Heights orchard.

Fig. 2—*Effect of water temperature on cherry cracking*—Ninety 'Bing' cherries of uniform size and maturity were harvested and separated into nine sample lots of 10 each. Each lot was placed in a separate beaker containing deionized water. Three beakers were maintained at 40ºC (104ºF), three were maintained at 30ºC (86 ºF), and three were maintained at 22ºC (72ºF). All fruits were examined at 30-minute intervals for cuticle cracking, and cracked fruits were removed from the beakers.

Fig. 3—*Effect of water quality on cherry cracking*—'Bing' cherries of uniform size and maturity were harvested and separated into four lots of 30 each. Each lot was placed in a separate beaker. One beaker contained deionized water (DW) at 22ºC (72ºF); another contained city water (CW) at 22ºC; another contained a 10% (w/v) sucrose solution (SS) at 22ºC; and another contained irrigation water (IW) at 16ºC (61ºF). All fruits were examined at 30-minute intervals for cuticle cracking, and cracked fruits were removed from the beakers.

Fig. 4—*Effect of water quality on water absorption in cherries*—'Bing' cherries of uniform size and maturity were harvested, separated into nine lots of 10 each, dipped in deionized water, blot dried, and weighed. Three lots were immersed in deionized water DW) at 22ºC (72ºF); three were immersed in city water (CW) at 22ºC; and three were immersed in 10% (w/v) sucrose solution (SS) at 22ºC. Every 2 hours, each cherry lot was removed from solution, blot dried, reweighed, and recorded. Water absorption was calculated as percent change in weight.

Fig. 5—*Effect of matrix on water absorption in cherries*—'Bing' cherries of uniform size and maturity were harvested and separated into nine lots of 10 fruits each. Three lots were dipped quickly into 10% (v/v) Formulation II, three into 20 % (v/v) Formulation II, and three into deionized water (DW). All fruits dried overnight at 22ºC and were weighed before immersion in DW. Every 2 hours, each cherry lot was removed from the DW, blot dried, and weighed.Water absorption was calculated as percent change in weight.

Fig. 6—*Effect of matrix on cherry fruit cracking*—The materials and methods were similar to those in Fig. 5, except that the cherries were examined for cracking after 9 and 11 hours in deionized water.

Fig. 7 and 8—*Effect of matrix and temperature on cracking of cherries at the stem bowl*—'Bing' and 'Rainier' cherries of uniform size and maturity were harvested and separated into two lots of 60 for each cultivar. One lot of each cultivar was dipped into 20% (v/v) Formulation II, and the other was dipped into deionized water (DW). The fruit dried at room temperature overnight. The fruit pedicel (stem) of each cherry was cut so that only 0.5 cm remained. Plastic containers were prepared with four layers of absorbent paper; DW was added to a level sufficient to cover the paper and the cherry shoulders when they were immersed in an inverted position. Treated fruits and controls were maintained separately at 30ºC (86ºF) and 45ºC (113ºF) and were examined for cracking at 30-minute intervals.

Fig. 9—*Suppression of cherry cracking in the field*—Four 'Bing' cherry tress of uniform growth and vigor were selected. Three branches of each tree were sprayed 2 weeks before harvest with one of the following treatments: 10% (v/v) Matrix II, 20% (v/v/) Matrix I, or DW (control). Overhead sprinklers were installed in each tree, and deionized water was pumped through the nozzles with an electric pump to provide 0.4 gallons water/minute per nozzle. In some cases, four nozzles per tree were installed to wet the fruit for at least 2 hours. Fruits were evaluated for cracking the next day.

Fig. 10—*Effect of formulation on water loss with and without pedicel (stem*)—Two hundred 'Sweetheart' cherries of uniform size and maturity were harvested. The pedicel was removed from 100 of the cherries; 50 were immersed in 10% (v/v) Formulation II and 50 were immersed in DW. The other 100 fruits with pedicel attached were split and treated as above. All treatments were transported from the field to the laboratory (approx. 45 minutes), and then rinsed with DW, blot dried, grouped in lots of 10, and weighed. The various lots were held at 22ºC and reweighed at various times; the percent water loss was recorded as a percent change in weight.

Results and discussion:

Field experiments: Initially, 'Chelan' cherries at various stages of maturity were sprayed with deionized water for 1 to 2 hours using backpack sprayers. However no cracking was observed. We then went to larger equipment in which an electric pump was used to pressurize a system that included microsprinklers installed within the tree canopy. We transported deionized water from the laboratory to the field in 55-gal plastic drums and applied 6 drums (330 gal.) of water in each experiment. In early experiments, we were unable to crack the cherries, but after revamping the system to direct more water onto the fruit from four microsprinklers we were successful in cracking 'Bing' cherries. In the meantime, we conducted some laboratory experiments to learn more about factors that contribute to cherry cracking. These experiments were helpful and some are described below.

We used thermocouples on fruit in the field to determine the relationship between air temperature and fruit surface temperature. We found that fruit surface temperature on the sun-exposed side of a cherry can be as much as 18°F warmer than air temperature (see Fig. 1). The differential between air and fruit temperature was larger than we expected and helps explain why cherries are more likely to split when the sun comes out and air temperature rises rapidly after a rain.

We examined the effects of temperature by immersing 'Bing' cherries in beakers of deionized water held constant at several temperatures (see Fig. 2). The effects of temperature are striking. At 104°F, all fruit cracked within 1.5 hours, whereas it took 3 hours at 86°F and 6.5 hours at 72°F.

Water quality also affected cracking. Cracking was delayed by city water, irrigation water, and a sugar solution as compared to deionized water (see Fig. 3). The electrical conductivity of city water, irrigation water and sugar solution was considerable whereas deionized water was near zero.

Water absorption by 'Bing' cherries was also influenced by water quality. Water absorption was decreased by city water and sugar solution relative to deionized water (see Fig. 4). Water absorption was also decreased by applying Formulation II to 'Bing' cherries before they were immersed in water (See Fig. 5).

Formulation II also substantially reduced cracking of 'Bing' cherries after 9 hours in water (see Fig. 6). In a specially designed experiment in which fruits were inverted on wet paper towels whose temperature was controlled at either 86°F or 113°F, cracking of the stem bowls was decreased and delayed by the formulation (see Fig. 7 for 'Bing' and Fig. 8 for 'Rainier').

In a field experiment, cracking of 'Bing' cherries was significantly reduced by two formulations (see Fig. 9). We tested two formulations, but chose to use Formulation II for most experiments, as it provided an attractive sheen on the cherries. We were unsuccessful in inducing cracking in 'Lapins' and 'Rainier' trees in the same orchard. We also had little success in cracking 'Chelan' or 'Sweetheart' cherries in the field. Thus, we need to improve our techniques further to induce a higher incidence of cracking. From our laboratory studies, we have findings that will help us modify our techniques.

In a different experiment designed to suppress post-harvest water loss from cherries, we harvested cherries directly into a container of the formulation. Half of the cherries had a pedicel (stem) and half did not. We harvested an equal number of fruits and placed them in a container of water (control). The fruits were transported to the laboratory, and all were rinsed with deionized water. Fruits were retained at 72°F for 72 hours. They were weighed periodically during that period to determine water loss (see Fig. 10). The green color of the stems was also examined, but differences were small. It should be noted, however, that the formulation was only on the fruit for 45 minutes before rinsing. We reasoned that if we left the fruit in the formulation longer, it would not simulate what a grower might experience when taking the fruit to storage. If we can design a method to keep the formulation on the fruit longer, we will likely see a bigger effect of the formulation on both stem color and water retention by the fruit.

Dr. Whiting compared Formulation I to an untreated control on several cherry cultivars in the field. He tested 'Chelan,' 'Bing,' 'Liberty Bell,' and 'Sweetheart' (data not shown). The only statistically significant difference between treated cherries and untreated controls was observed for 'Liberty Bell' in which cracking was significantly reduced by the formulation.

In summary, a number of promising experiments were completed during 2002. Several of these need to be confirmed and expanded in the future. A new proposal has been submitted requesting funding for two additional years to study the formulation for suppression of cherry cracking and post-harvest stem browning and water loss.

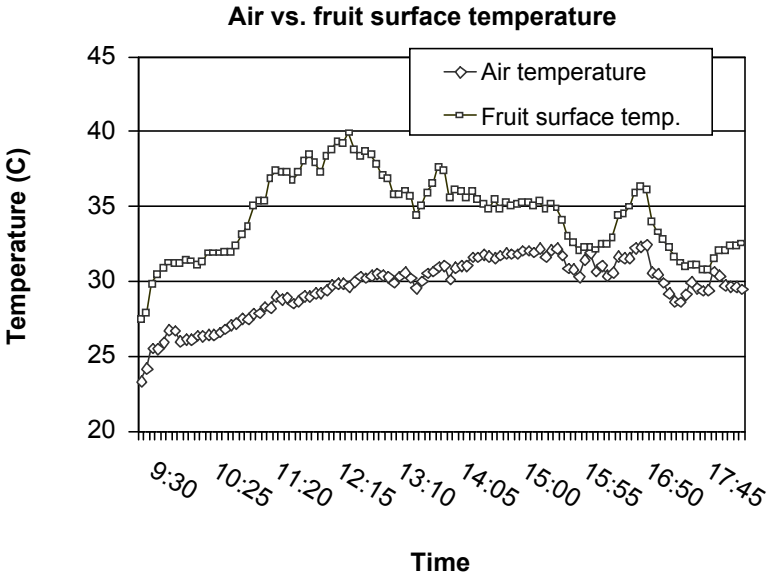

Fig. 1. Air temperature versus cherry fruit surface temperature on sun-exposed side. Lower line is air temperature and upper line is fruit surface temperature.

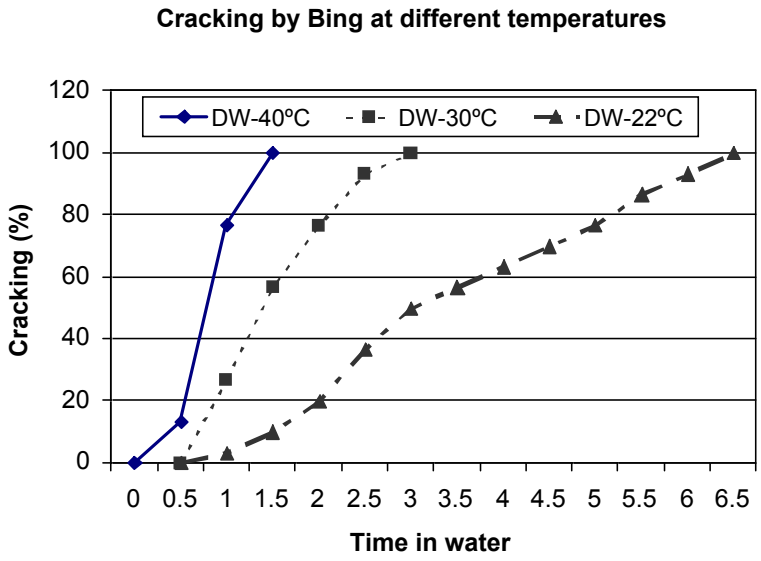

Fig. 2. Effect of water temperature on cracking of 'Bing' cherries immersed in water.

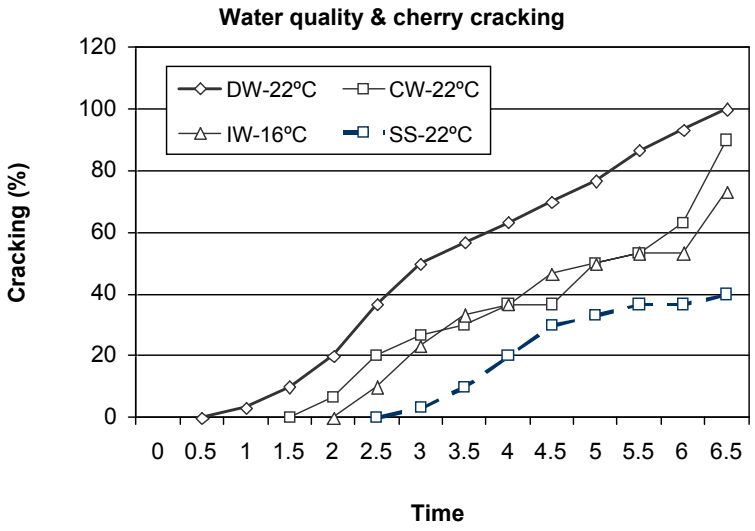

Fig. 3. Effect of water quality on 'Bing' cherry cracking. DW = deionized water; CW = city water; IW = irrigation water; SS = 10% (w/v) sucrose solution.

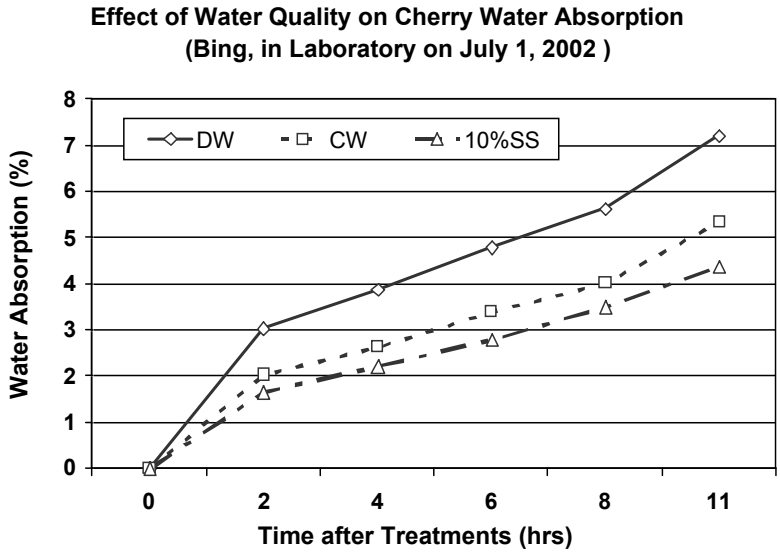

Fig. 4. Effect of water quality on water absorption by 'Bing' cherries. DW = deionized water; CW = city water; SS = 10% (w/v) sucrose solution.

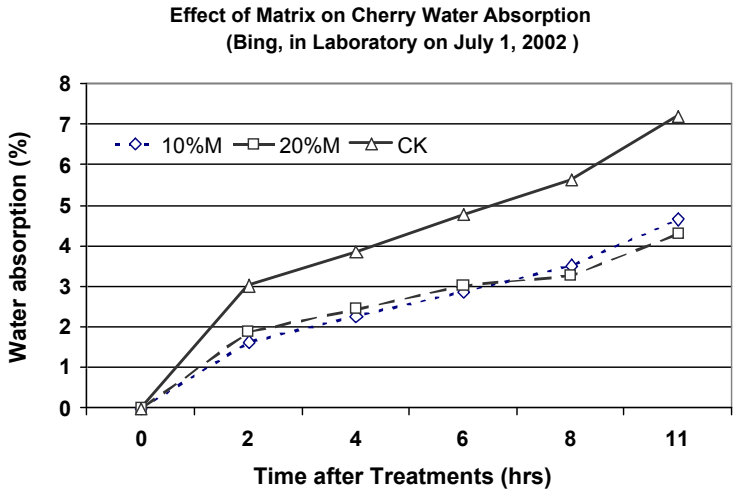

Fig. 5. Effect of Formulation II (10 and 20%) on water absorption by 'Bing' cherries

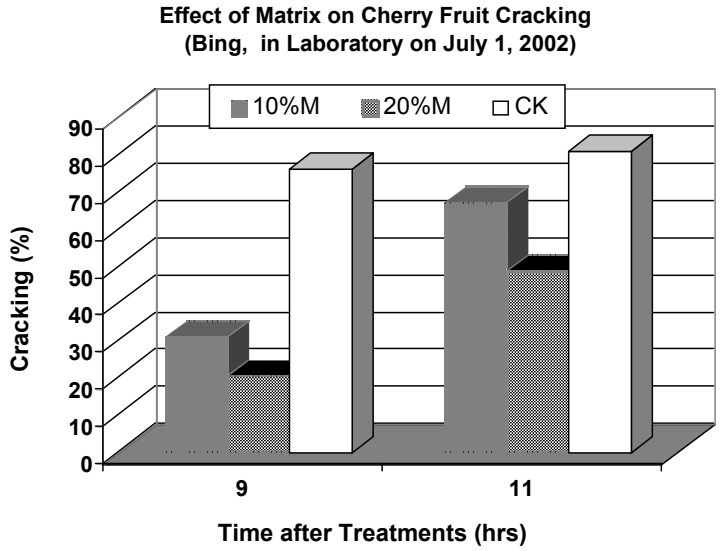

Fig. 6. Suppression of 'Bing' cherry cracking when formulation II was applied at 10 and 20% [10% M and 20% M] vs. control (CK).

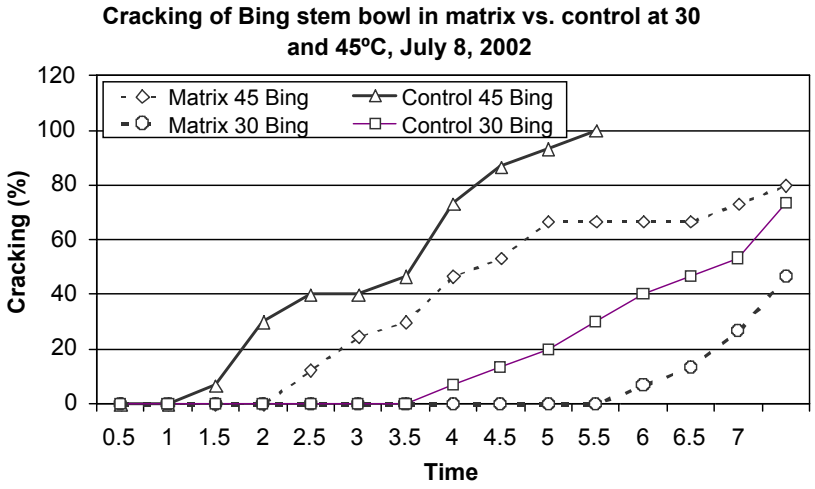

Fig. 7. Effect of formulation and temperature on cracking of 'Bing' cherries at the stem bowl.

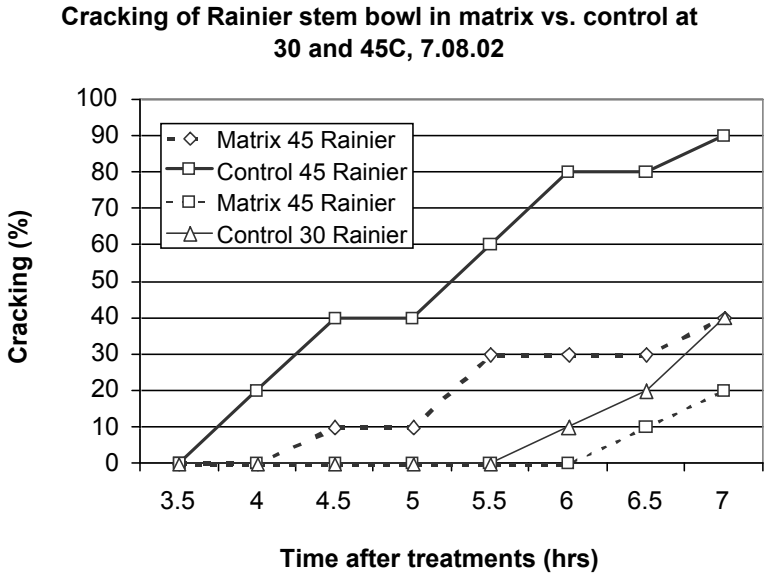

Fig. 8. Effect of formulation and temperature on cracking of 'Rainier' cherries at the stem bowl.

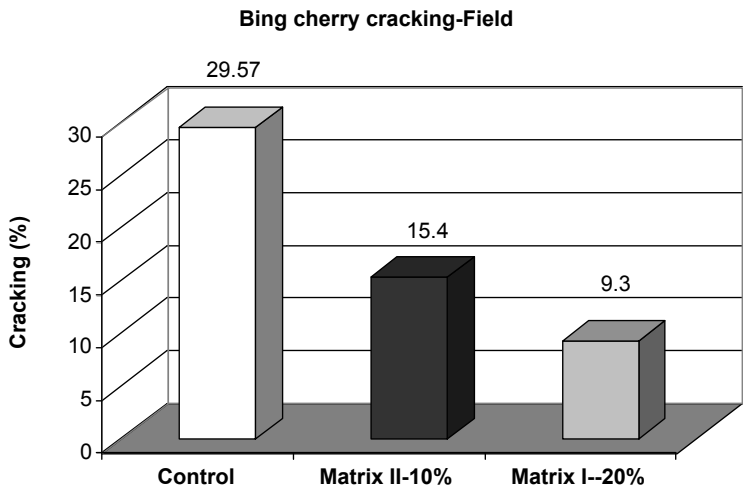

Fig. 9. Suppression of cracking of 'Bing' cherries with two formulations applied to cherries in the field.

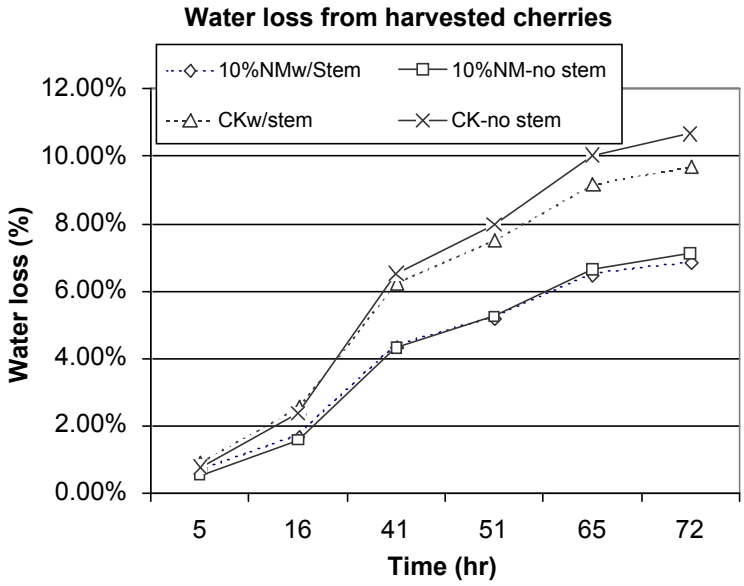

Fig. 10. Effect of formulation on water loss from harvested 'Sweetheart' cherries at room temperature. Cherries with and without the pedicel (stem) were compared.

Budget:
Title: New tactic for suppressing cracking of cherries
PI: Larry Schrader
Project duration: 1 year
Current year: 2002
Project total: $16,780 for 1 year (2002)
Current budget request: See new project proposal.

Year	Year 1 (2002)
Total	**$16,780**

Current year breakdown

Item	Year 1 (2002)
Salaries[1]	**$ 9,087**
Benefits (27%)	**2,453**
Wages[2]	**1,500**
Benefits (16%)	**240**
Equipment	
Supplies[3]	**3,000**
Travel[4]	**500**
Miscellaneous	
Total	**$16,780**

[1]Salary requested for an agricultural research technologist II (25% time) for Schrader. A budget reduction at WSU in 2001 reduced technical support for Schrader to 0.75 FTE.

[2]Time-slip help for Whiting.

[3]Supplies include pumps to be used in "rain simulation" tests, sprinkler heads etc. for overhead application of water, mylar bags to enclose trees, and other general supplies.

[4]Travel to experimental plots.

Summary of total cost for final report: $16,780

CONTINUING PROJECT REPORT **YEAR 3/3**
Project # CH-01-07

Title: Chemical bloom thinning of sweet cherry to increase fruit size

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Dana Faubion, WSU Cooperative Extension, Yakima, WA
Matthew Whiting, WSU-IAREC, Prosser, WA

Research Assistants: Helen Cahn, OSU-MCAREC, Hood River, OR
Tory Schmidt, WTFRC, Wenatchee, WA
Frances Ceya, WSU, Yakima, WA

Background
The sweet cherry industry of the Pacific Northwest demands large, firm fruit for the fresh market. Larger fruit commands higher prices in the market. Firmness and soluble solids content of sweet cherries tend to increase with increasing fruit size. Thus, producing large fruit is critical for optimizing economic returns of fresh sweet cherries.

New rootstocks that confer precocity and compact tree size are gaining popularity in the Pacific Northwest. However, they often shown a tendency to overset, resulting in high yields of small fruit of reduced commercial value. Excessive crop load results in reduced fruit size due to competition of fruits for limited reserves and/or current photosynthates. Therefore, reducing crop load in sweet cherry trees is expected to help produce larger fruit.

Our strategy to reduce crop load consists in the use of chemical bloom thinning sprays. Compounds under evaluation include ammonium thiosulfate, lime sulfur combined with a fish-derived oil, and a non-caustic vegetable oil emulsion that reduce bloom intensity by preventing flowers from opening (and consequently preventing cross pollination). Our initial results (2001 and 2002) in 'Lapins' and 'Bing' cherry showed that ATS and vegetable oil can reduce bloom and crop load. However, the effects on fruit size have been inconsistent. More work on chemical bloom thinning is needed to better understand the relationship between bloom intensity, crop load and final fruit size in sweet cherries to develop reliable strategies to increase fruit size.

Objectives
- To determine the efficacy of chemical bloom thinning agents in reducing crop load.
- To determine the effect of crop load reduction on fruit size and quality.

SIGNIFICANT FINDINGS FOR 2002
- The effect of chemical bloom thinners continued to vary greatly among locations. Similar to the previous year, reductions in crop load were not always reflected in larger fruit size.
- The strongest responses to chemical treatments appeared to occur when with high initial crop loads. Crop load reductions have often been excessive, resulting in larger fruit but production of yields too low to be economically attractive.

- There is still insufficient data to conclude on the relative efficacy of the chemical bloom thinners being used.

- In some cases, the chemical treatments increased fruit firmness and total soluble solids content of fruit.

METHODS

The study is being conducted in grower cooperators' or research sweet cherry orchards in Oregon and Washington. 'Bing' and 'Lapins' trees on dwarfing rootstock were used during 2002 for testing different chemical spray treatments. Treatments consisted of:

1. Control trees, not sprayed.
2. Crocker fish oil + lime sulfur 2% (CFO + LS, sprayed at 25% FB and again at 85% FB).
3. Vegetable oil emulsion (VOE; 4% a.i., sprayed at bloom stage 6 and again at 75% FB).
4. Ammonium thiosulfate (ATS; 2% v:v; sprayed at 25% FB and again at 85% FB).

One branch containing wood from 1 to 4 years of age was chosen per tree for data collection. Measurements included basal diameter at branching point, total branch length, number of individual flowers, number of green fruit when fruit measured 1 cm diameter, number of harvested fruit per branch and weight of fruit harvested from whole branch. Total yield per tree was obtained from each experimental tree. A random sample of 25 fruit was collected from each branch to determine diameter, firmness and average fruit weight.

Results

Prosser, WA ('Bing'/Gisela 5)

All chemical sprays significantly reduced crop load compared to controls. Yields of control trees averaged 68 lb/tree (31% fruit set) vs. 15-24 lb/tree (6% to 13% fruit set) in sprayed trees. All spray treatments increased average fruit weight from 5.4 g in controls to 7.0-7.6 g in sprayed treatments. Chemical bloom thinning resulted in significantly higher percentages of 11½-row fruit (81%-92%) compared to controls (47%). Average fruit firmness was significantly increased by CFO + LS (242 g/mm vs. 296 g/mm in controls), while the other treatments produced fruit with firmness similar to that of controls. ATS and CFO + LS significantly increased total soluble solids to 24^{o} Brix compared to 20^{o} Brix in controls.

The Dalles, OR ('Bing'/Gisela 5)

Results at this site were not as clear-cut as in Prosser. Average tree yields for all treatments were about 40 lb/tree. Fruit set of controls was 52%, vs. 39% to 42% fruit set for sprayed trees. Compared to Prosser, average fruit weight in The Dalles was large for all treatments (10.0 g to 10.8 g), including controls (10.4 g), corresponding to an average row size of 9½ in all cases. Fruit firmness was high in all cases, ranging from 314 g/mm in controls to 323 g/mm to 353 g/mm for the chemical spray treatments.

Hood River, OR ('Lapins'/Gisela 11)

VOE was not tested in this orchard due to insufficient trees for adequate replication. Tree responses were very variable, resulting in no significant effects of ATS or LS spray treatments on fruit set, crop load reduction or fruit size. Fruit set varied from 27% to 30%, with average yields ranging from 28 lb/tree (ATS) to 46 lb/tree (control and LS). Average fruit weight ranged from 12.0 g to 13.4 g (30.3 to 31.6 mm diameter). Average row size was 9 for LS and controls and 8½ for ATS. For all treatments, average fruit firmness was about 235 g/mm and total soluble solids averaged about 18^{o} Brix.

It is interesting to mention that a portion of this 'Lapins' orchard consists of rows covered with a woven polypropylene fabric. Under this condition, ATS significantly reduced fruit set and crop load although

fruit size was not significantly increased. Fruit set for controls was 45% (57 lb/tree), while ATS and LS resulted in fruit set of 20% (40 lb/tree) and 39% (56 lb/tree), respectively. Fruit weight ranged from 12.0 g in controls to about 12.5 for LS and ATS, with an average diameter of about 31 mm, equivalent to a size of 9-row. Average fruit firmness and total soluble solids was about 250 g/mm and 18° Brix, respectively, for all treatments.

Wenatchee, WA ('Bing'/Gisela 5)
Although chemical sprays had no significant effect on crop load reduction, there was a trend for reduced yield in response to the spray treatments (average yield for control trees was 50 lb/tree, compared to 36 lb/tree to 45 lb/tree for the spray treatments). Interestingly, however, significant increases in average fruit weight were obtained with the use of ATS, CFO+LS and VOE. Average fruit weight for controls was 6.6 g (24.7 mm diameter; 11-row), 8.0 g to 8.3 g (26.2 mm to 27.0 mm diameter; 10½-row) for VOE and ATS, and 8.9 g for CFO+LS (27 mm diameter; 10-row). ATS significantly increased °Brix compared to the controls (18.9 vs. 16.7), while all chemicals increased fruit firmness (234 g/mm vs. 258 to 270 g/mm).

Yakima, WA ('Bing'/Gisela 6)
Chemical bloom thinning treatments showed no significant effects on fruit set, crop load reduction or fruit size. Average fruit size for all treatments at this site ranged from 8.6 g to 9.7 g (24.5 mm to 25.6 mm diameter), equivalent to a row size of 11 to 10½. No effects were detected on soluble solid content, with °Brix averaging 18.5 to 19.3.

Chemical bloom thinning of sweet cherry has not yet been demonstrated to consistently reduce crop loads and increase fruit size. Reasons for the variable responses may involve differences in spray coverage due to equipment used, tree physiological condition at the time of treatment (possible stresses) and climatic conditions around the time of treatment application. During 2003 we will repeat these treatments and attempt to clarify the role of correlative factors on tree responses.

BUDGET
Title: Chemical bloom thinning to increase fruit size in sweet cherry**.**
PI: Roberto Núñez-Elisea
Duration: 2001-2003
Project total (3 years) $17,000
Current year request: $7,000

Year	Year 1 (2001)	Year 2 (2002)	**Year 3 (2003)**
Total	$4,000	$6,000	**$7,500**

Current year breakdown:

Item	Year 1 (2001)	Year 2 (2002)	**Year 3 (2003)**
Salaries - FRA	$4,000	$4,398	**4090**
OPE (51.58 %)		$352	**2110**
Service and supplies[1]		$500	**300**
Travel[2]		$750	**500**
Total	$4,000	$6,000	**7,000**

[1] Spraying equipment, photographic supplies, spray chemicals.
[2] Travel to experimental plots.

CONTINUING PROJECT REPORT **YEAR 3/3**
PROJECT NO.: CH-01-18 (13C-3355-7202)

TITLE: Quantifying Limitations to Balanced Cropping

Principal Investigator: Matthew Whiting
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Cooperators: Don Elfving, Horticulturist, WSU-TFREC
Julie Tarara, Research Horticulturist, USDA-ARS

OBJECTIVES:
To field-validate balanced cropping model and develop and evaluate practical strategies for moderating sweet cherry crop load.

1. To investigate the relationships among tree vigor (i.e., leaf area, shoot growth, trunk expansion, root growth), fruit yield, fruit quality, and yield potential in subsequent years (i.e., flower bud initiation, bloom density, fruit set and yield); in short, investigate whole-tree source-sink relations.

2. To quantify the partitioning of cropping resources, such as photosynthates and nitrogen, between the developing tree canopy, flower buds, and fruits to balance yields with optimized fruit size.

SIGNIFICANT FINDINGS:
In spring, 2002 we imposed different strategies designed to reduce the number of fruit per tree and balance crop load with vegetative vigour (i.e., whole-canopy fruit-to-leaf area ratio) of 'Bing' on both Gisela 5 and 6. Based on spur and fruit bud counts of entire trees (see report 'High Density Orchard Management') whole-tree thinning was targeted to leave approximately 2000 fruit per tree (≈ 50% of potential). Spur 'extinction' (i.e., the removal of complete spurs) was compared to blossom thinning.

- thinning crop load of 'Bing'/Gisela 5/6 trees improves fruit quality: high quality fruit (i.e., 70-92% larger than 11.5-row) can be grown on Gisela series rootstocks
- 50% spur thinning and 50% blossom thinning reduced crop load similarly
- fruit-to-leaf area ratio is higher (i.e., worse) for spur-thinned vs. blossom-thinned
- thinning method affected fruit quality and yield
- number of fruit per tree, fruit soluble solids, and yield efficiency were similar for blossom- and spur-thinned trees
- for both Gisela 5- and 6-rooted trees, blossom thinning resulted in higher yields and larger fruit compared to spur thinning
- the best combination of yield and quality was blossom-thinned Gisela 6 trees which yielded 41 lbs per tree of fruit averaging 21.4 ^{o}brix, 7.8 g, and 85% 11.5-row and larger

In 2002 we also studied canopy carbon acquisition and the relative roles of different sweet cherry leaf types (i.e., shoot leaves *vs*. non-fruiting spur leaves *vs.* fruiting spur leaves). This experiment delineated the capacity for (i.e., leaf surface area), and efficiency of net photosynthesis within sweet cherry canopies towards understanding whether or not different leaf types more/less effective as carbohydrate producers. With this knowledge, more informed management decisions can be made, particularly with respect to training and pruning.

- spur leaves expand rapidly in the spring and achieve maximum area ~ 40 days after bud break
- maximum shoot leaf area occurs shortly after terminal bud set (≈ 80 days after bud break)
- leaf area/shoot is ca. 4-fold greater than leaf area/one-year-old non-fruiting spur and twice as great as leaf area/fruiting spur
- leaf net photosynthetic rate increases throughout stages I and II of fruit development and reach seasonal maxima during stage III
- leaf net photosynthetic rate and dark respiration (i.e., daily carbon balance) are similar among leaf types
- the presence of fruit did not affect leaf net photosynthesis
- the relative assimilation potential per annual growth segment is as follows: shoots > fruiting spurs > non-fruiting spurs

METHODS:

Acquisition of cropping resources. The laws of supply and demand apply to sweet cherry production. Carbohydrate supply is finite and directly proportional to the rate of photosynthesis and the area of photosynthetically active tissue. This project has already identified the daily and seasonal trend in whole-canopy net photosynthesis, the effects of crop load and fruiting, and developed a model of balanced production (i.e., yield and quality) on Gisela-rooted trees. In the current year we propose to continue investigating practical means of applying our model of balanced cropping on mature heavily-cropped 'Bing'/Gisela 5 trees. These include spur thinning ('extinction'), blossom thinning, and modified pruning. In addition, crop load management experiments will be carried out on Gisela-rooted trees in their first year of cropping to examine how early thinning alters our model of balanced cropping in mature trees.

To better understand the role that carbohydrate assimilation after harvest has on yield potential and fruit quality in the following year (2003), entire trees were defoliated completely at approximately 30 and 60 days after harvest. This winter, storage reserves in perennial tissues will be quantified by analyzing for carbon and nitrogen. In 2003, crop load will be standardized across treatments and vegetative growth, fruit yield, and fruit quality will be evaluated.

In addition, the effect of leaf loss during the postharvest interval will be studied in relation to canopy gas exchange and tree growth and fruiting in the subsequent season. In 2003, trees will be partially defoliated by manually removing ca. 10, 25, and 50% of existing leaf area.

Partitioning of cropping resources. This project has documented the competitive relationship between vegetative vigor, crop load, and fruit quality in 'Bing'/Gisela 5 trees (Whiting, 2002). In addition, different leaf types have been characterized for their relative capacity as carbohydrate sources (Whiting and Lang, 2003). What remains to be clearly identified is the relationship among various carbohydrate sources (e.g., leaves) and sinks (e.g., fruit and shoots) and the role of the different leaf types. For example, although shoots are the greatest potential source of carbohydrates (see Table 2), it is not known what role they play at supporting fruit growth. To accurately identify source-sink relationships different leaf types will be exposed to traceable carbon isotopes (e.g., $^{13}CO_2$) and fruit, leaves, and wood will be destructively sampled and analyzed for the presence of ^{13}C.

RESULTS & DISCUSSION:

From the past years' results, we now have a better understanding of the temporal and spatial variability in whole-tree growth and development and the nature of competition for carbohydrate resources. Shoot growth, leaf expansion, and fruit growth all occur during the preharvest interval (*i.e.*, full bloom – harvest) and compete for carbon resources produced during the reactions of

photosynthesis. This research has shown that the supply, and/or partitioning of, carbohydrate resources limit fruit yield and quality. In addition, although it was not a goal of this research to provide thinning recommendations, our results have documented the effect of crop load removal on fruit quality variables that should contribute to a basis upon which potential thinning strategies can be rationalized. The balanced cropping model suggested that 'Bing'/Gisela 5 trees at full canopy are optimized at approximately 2000 fruit per tree. In 2002 we tested two methods of achieving this target: spur thinning and blossom thinning. Both approaches improved fruit quality dramatically compared to the control trees. However, blossom thinning was a more effective technique, yielding more and better quality fruit than spur thinning (Table 1). This occurred because spur thinning, while reducing crop load, also reduced canopy leaf area (i.e., those leaves from the fruiting spurs). In contrast, blossom thinning targeted only carbohydrate sinks, favorably impacting canopy fruit-to-leaf area ratios. It will be interesting to monitor tree yield, and fruit quality in subsequent seasons. Blossom thinning will be required every year whereas spur thinning may only be required every second or third year.

Table 1. Effect of blossom and spur thinning on fruit yield and quality of 8-year-old 'Bing'/Gisela 5/6 sweet cherry trees.

Treatment	# fruit/tree	Tree yield (kg)	Fruit mass (g)	Fruit soluble solids	% ≤12-row	% ≥11.5-row
Control	3827 a	22.8 a	5.9 c	19.9 a	48 a	52 b
Blossom	2250 ab	16.6 b	7.4 a	21.6 a	14 b	86 a
Spur	2053 b	13.4 c	6.6 b	22.0 a	24 b	76 a

We now have a detailed understanding of carbohydrate production within sweet cherry canopies. Among annual growth segments, shoots possess the greatest potential as carbohydrate sources due to their superior leaf area and similar photosynthetic rates (Table 2). In addition, most shoots are situated in the tree's periphery, and therefore in an environment that favors high photosynthetic rates (i.e., well sunlit). This data suggests that each individual fruiting spur (i.e., 2-year-old and older spurs) has the leaf area to support slightly more than one fruit because fruit quality declines at less than 5.5 leaves per fruit (see 2001 Report 'Quanitifying Limitations to Balanced Cropping'). However, fruiting spurs usually bear several fruit. Therefore, to maximize fruit quality, one-year-old non-fruiting spur and shoot leaf area must supplement fruiting spur leaf area with growth resources. Pruning strategies that improve branch fruit-to-leaf area ratios and position non-fruiting leaf area (spur or shoot) closer to fruiting spurs must be adopted. Clearly, lengthy, un-pruned shoots with few lateral breaks are undesirable in this regard.

Table 2. Components of the relative assimilation potential of different annual sweet cherry growth segments.

Annual growth segment	# leaves/spur or shoot	Leaf area per spur or shoot	Net photosyn. ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	Relative assimilation potential
Shoot	15 a	465 a	10.6 a	100
1-yr-old spur	5 c	115 c	10.3 a	22
2-yr-old spur	6.5 b	195 b	9.9 a	36
≥3-yr-old spur	6 b	216 b	9.9 a	40

Carbon acquisition and partitioning within sweet cherry trees remains critical to understand considering its fundamental relation to tree productivity and fruit quality. Practical strategies (e.g., spur and blossom thinning) will be sought based upon empirically developed balanced cropping models. Already this project has provided the first quantitative information integrating photosynthetic activity in PNW sweet cherries across the entire tree canopy and within different canopy architectures (Whiting and Lang, 2001). This information becomes more critical as younger and smaller trees with limited canopies and resource storage potential are cropped, either via new rootstocks or intensive cultural practices. Information transfer will occur rapidly through research results reported at industry/extension meetings (*e.g.*, Cherry Institute, Oregon Hort Society, IDFTA), local grower meetings, and publication of results and recommendations in industry (*e.g.*, *Good Fruit Grower*) and scientific (*e.g.*, *Journal of ASHS*, *Scientia Horticulturae*) periodicals.

Literature cited/Publications:

Whiting, M.D. 2002. The importance of photosynthesis to fruit quality. Proceedings of the 116th Annual Mtg. Oregon Hort. Soc. In press.

Whiting, M.D. 2001. Improving Sweet Cherry Fruit Quality: Genetic, Horticultural, and Physiological Concepts. Proceedings of 97th Annual Meeting of the Washington State Hort. Assoc. pp. 194-197

Whiting, M.D. and G.A. Lang. 2001. Canopy architecture and cuvette flow patterns influence whole-canopy net CO_2 exchange and temperature in sweet cherry. HortScience 36: 691-698.

Whiting, M.D. and G.A. Lang. 2003. Potential for gas exchange in sweet cherry: the role of different leaf types. Acta Hort. in review.

BUDGET:

Title: Quantifying Limitations to Balanced Cropping
PI: Matthew Whiting
Project duration: 3 years
Project total (3 years) $76,566
Current year request: $19,066

YEAR	2001	2002	**2003**
Total	$15,000	$42,500	**$19,066**

Current year breakdown

ITEM			
Salaries[1]		5,797	**6,083**
Benefits (28%)		1,623	**1,703**
Wages[2]	5,600	8,000	**8,000**
Benefits (16%)	900	1,280	**1,280**
Equipment	4,500	21,800	
Supplies[3]	3,000	3,500	**1,000**
Travel[4]	1,000	500	**1,000**
Miscellaneous			
TOTAL	$15,000	$42,500	**$19,066**

[1] One-sixth annual salary for Mr. Efrain Quiroz.

[2] 4 months student labor (May-August) for assisting with chamber studies, collection of canopy physical data (i.e., leaf area, light interception), and fruit quality analyses

[3] Includes labeled $^{13}CO_2$, all chamber materials (e.g., mylar, velcro, pvc) and gas analysis consumables

[4] Travel to plots

CONTINUING PROJECT REPORT **YEAR 3/3**
WTFRC Project # CH-01-20 (Modified) **WSU Project #3298**

Project Title: Bioregulator Uses for Vigor Management, Stimulating Cropping and Facilitating Mechanical Harvesting in Sweet Cherry

PI: Don C. Elfving, Horticulturist
Organization: WSU Tree Fruit Research and Extension Center, Wenatchee, WA

Cooperators: Steven R. Drake, Horticulturist, USDA/ARS, TFRL, Wenatchee, WA
James R. McFerson, Horticulturist and Manager, WTFRC
Thomas D. Auvil, Horticulturist, WTFRC
Matthew D. Whiting, Assistant Horticulturist, WSU-IAREC, Prosser, WA
Tory Schmidt, Agricultural Technician, WTFRC
Dwayne Visser, Agricultural Research Technologist II, WSU-TFREC, Wenatchee, WA

Objectives: Eight trials with bioregulators on sweet cherry were initiated in 2002; all the trials were located in grower orchards in north- or south-central Washington. Six trials from 2001 and one from 2000 were carried over into 2002, including two trials in The Dalles, OR. Twelve of the trials, including five of the 2002 trials, were designed to more precisely define the individual roles of prohexadione-Ca (Apogee®) and ethephon (Ethrel®) on cherry tree growth, flowering and productivity and to test Ethrel application rates and timings for bloom stimulation efficacy. The other three trials set up in 2002 were designed to explore Ethrel and AVG (ReTain®) effects on loosening cherries for mechanical harvest while retaining suitable fruit quality following harvest. Data have been or will be collected as necessary in each trial on flowering, shoot and trunk growth, yield, fruit removal force, fruit size, and fruit quality. One trial from 2000 and six trials from 2001 were followed in 2002 for flowering and fruiting effects of year 2000 or 2001 treatments.

Significant Findings (trial initiated 2000):
Trees in the one trial from 2000 ('Bing'/Mazzard) in which flowering and yield in 2001 were nearly tripled by two applications of a tank mix of Apogee and Ethrel in 2000 were again sampled for flower bud density in April, 2002 (no further treatments applied). Interestingly, the treatment in 2000 that tripled bloom and yield in 2001 had twice as many flower buds on spurs in 2002, suggesting that successful stimulation of precocity with bioregulators in sweet cherry might shift the vegetative/reproductive balance toward flowering in a more permanent way. Unfortunately, postbloom spring frost eliminated the entire crop in this orchard, preventing any beneficial effects on yield in 2002 from being determined.

Significant Findings (trials initiated 2001):
1. Apogee and Ethrel on non-cropping, third leaf 'Gibraltar'/Mahaleb sweet cherry trees (The Dalles, OR): Apogee (6 oz/100 gallons+0.1% v/v Regulaid), Ethrel (0.6 pt/100 gallons+0.1% v/v Regulaid) or the tank mix combination was applied to trees in the trial on 21 May and again on 11 June 2001. The objectives were to 1) follow terminal shoot growth response to the treatments; 2) evaluate treatment effects on flowering and yield in 2002; and 3) assess the individual contributions of Apogee and Ethrel to any improvement in flowering and yield in 2002. Flower bud density in 2002 was significantly increased by three of four treatments in which Ethrel was applied twice in 2001. Flowering was not improved by Apogee applied alone or together with Ethrel. These results suggest that Apogee has no effect on return bloom in sweet cherry, similar to the effects observed and already reported on apple and pear. Studies in 2002 are concentrating on evaluation of Ethrel treatment strategies to stimulate precocity. Yield was not increased despite the increased

bloom. This may have occurred because most of the increase in bloom came from buds on previous season's shoots. It is not known whether these flowers are as capable of fruit set as flowers that originate from spurs.

2. Apogee and Ethrel on non-cropping, third leaf 'Bing'/Mazzard sweet cherry trees (The Dalles, OR): Treatments, application dates and objectives were identical to the 'Gibraltar' trial described above. This block was summer pruned in June, 2001, shortly after the second round of applications. Any treatment that included Ethrel resulted in some gummosis and dieback of weaker, summer pruned shoots during the summer of 2001. There were no flowering differences in 2002.

3. Apogee and Ethrel on non-cropping, third leaf 'Lapins'/Mazzard sweet cherry trees (East Wenatchee): Apogee (6 oz/100 gallons+0.1% v/v Regulaid), Ethrel (0.6 pt/100 gallons+0.1% v/v Regulaid) or the tank mix combination was applied to trees in the trial on 15 May and again on 5 June 2001. The objectives were to 1) evaluate terminal shoot growth response to the treatments in the 'Lapins' cultivar for the second time; 2) evaluate treatment effects on flowering and yield in 2002; and 3) assess the individual contributions of Apogee and Ethrel to any improvement in flowering and yield in 2002. These treatments were the same as for the previous two experiments described above. Any treatment that included two applications of Ethrel produced greater flower bud density than single or no Ethrel treatments. Apogee had no effect on return bloom. Despite detectable differences in bloom density associated with treatments, flowering was very light in this block and yield data were not collected.

4. Apogee and Ethrel on non-cropping, third leaf 'Bing'/Mazzard sweet cherry trees (East Wenatchee): Apogee (6 oz/100 gallons+0.1% v/v Regulaid), Ethrel (0.6 pt/100 gallons+0.1% v/v Regulaid) or the tank mix combination was applied to trees in the trial on 17 May and again on 7 June 2001. The objectives were to 1) assess the reproducibility of terminal shoot growth responses to treatments that resemble the optimum treatments in 2000; 2) evaluate treatment effects on flowering and yield in 2002; and 3) assess the individual contributions of Apogee and Ethrel to any improvement in flowering and yield in 2002. In 2002 there were no differences in flowering in this block due to 2001 treatments.

5. Apogee and Ethrel on non-cropping, second-leaf 'Bing'/Mazzard sweet cherry trees (East Wenatchee): All possible combinations of Apogee (6 oz/100 gallons+0.1% v/v Regulaid) and/or Ethrel (0.5 pt/100 gallons+0.1% v/v Regulaid) were applied alone or in the tank mix on 29 May only, on 19 June only, or were applied on both dates (16 treatments total). The objectives were to 1) evaluate terminal shoot growth response to the treatments in very young 'Bing' trees; 2) evaluate treatment effects on flowering and yield in 2002; and 3) assess the individual contributions of Apogee and Ethrel to any improvement in flowering and yield in 2002. There were no treatment effects on flowering in 2002. These trees are too young for this kind of treatment because they have not accumulated any sizeable amount of spur wood.

6. Apogee and Ethrel on non-cropping, fifth-leaf 'Attika,' 'Bing' and 'Regina'/Mazzard sweet cherry trees (Prosser): Apogee (6 oz/100 gallons+0.1% v/v Regulaid), Ethrel (0.6 pt/100 gallons+0.1% v/v Regulaid) or the tank mix combination was applied to trees in the trial on 18 May and again on 8 June 2001. These treatments were repeats of similar treatments applied once to the same trees in 2000. The objectives were to 1) follow terminal shoot growth response to the double application treatments in 2001; 2) evaluate treatment effects on flowering and yield in 2002; and 3) assess the individual contributions of Apogee and Ethrel to any improvement in flowering and yield in 2002. Just as the cultivars responded to the treatments differently in terms of growth, they also responded quite differently in terms of flowering and yield. In 'Attika,' Ethrel increased bloom and yield, while Apogee had no effect. In 'Bing,' Ethrel increased flowering to a small degree but had

no yield effect. Apogee did not affect flowering or yield. In 'Regina,' there was no effect of either Apogee or Ethrel on flowering or yield. This trial demonstrates that sweet cherry cultivars can respond very differently to the same bioregulator treatments.

Significant Findings (trials initiated 2002):

1. Effects of Ethrel and ReTain on fruit loosening and fruit quality of sweet cherries for mechanical harvest (Pasco): ReTain (50 or 100 g a.i./acre) was applied with the Proptec airblast sprayer (100 gallons/acre) to 7-year-old cropping 'Bing'/Mazzard trees on 15 June 2002. Ethrel was also applied to trees treated with ReTain either as a single spray on that date (3 pt/acre in 100 gallons/acre) or as two sprays (1.5 pt/acre in 100 gallons/acre) on 15 and 21 June 2002. Fruit samples were collected on 15, 21, and 26 June, and fruit removal force was determined on the same dates. Fruit treated with ReTain only had fruit removal forces equivalent to the control on all sample dates. Treatment of ReTain-treated fruit with Ethrel resulted in significantly reduced fruit removal force; by 26 June the fruit that received 100 g/acre ReTain plus two applications of Ethrel at 1.5 pt/acre had a fruit removal force below the 300 g level considered desirable for fruit to be mechanically harvested. ReTain did not appear to protect Ethrel-treated fruit from firmness loss; the looser the fruit, the lower the firmness. There was no effect on fruit size or color rating. Fruit treated with both ReTain and Ethrel had slightly less soluble solids and titratable acidity; solids/acid ratios were unchanged. There was no clear effect of ReTain or ReTain+Ethrel on incidence of tears or cracks.

2. Ethrel concentration and application timing effects on fruit loosening and fruit quality of sweet cherries for mechanical harvest (Pasco): Ethrel (3 pt/acre) was applied on 15 June or 21 June 2002, Ethrel (4 pt/acre) was applied on 15 June, and Ethrel (1.5 pt/acre) was applied on both 15 and 21 June to 7-year-old cropping 'Bing'/Mazzard trees. Final fruit assessments were made on 26 June 2002. Fruit removal force was reduced to exactly the same extent by Ethrel at 4 pt/acre, at 3 pt/acre applied 15 June, and by Ethrel at 1.5 pt/acre applied twice. Ethrel at 3 pt/acre applied only five days before final measurements did not reduce fruit removal force as much as the other treatments. In contrast to 2001, Ethrel concentration did not have any significant effect on fruit removal force in 2002. Applying Ethrel closer to harvest (more mature fruit) did not accelerate the abscission process. Again, the looser the fruit, the more flesh firmness was reduced. In this experiment there were no effects of any treatment on fruit size, color, solids content or cracking, but the loosest fruit had slightly lower titratable acidity although solids/acid ratios were unaffected.

3. Effect of water volume on Ethrel-mediated fruit loosening and fruit quality of sweet cherries for mechanical harvest (Pasco): Ethrel (3 pt/acre) was applied to 7-year-old cropping 'Bing'/Mazzard trees in 50, 100 or 200 gallons of water per acre to assess effects of Ethrel rates (per acre) vs. Ethrel concentrations (per 100 gallons) on fruit removal force, fruit quality and incidence of gummosis. Ethrel loosened fruit and reduced flesh firmness to the same extent regardless of water volume. Ethrel in 200 gallons of water per acre reduced soluble solids content of fruit, but there were no other effects on fruit quality. Gummosis ratings have yet to be completed.

Results and Discussion

The flowering results from trials established in 2001 showed clearly that Apogee was not contributing in any significant way to improved flowering in young sweet cherry trees, despite effects on shoot growth. As a consequence, the 2002 precocity research program is focused almost entirely on Ethrel for bloom stimulation. Sweet cherry cultivars appear to be quite different in their responses to Apogee and Ethrel. This observation suggests that it may be difficult to generalize bioregulator results with one sweet cherry cultivar to other cultivars. The increased bloom seen in 2002 from treatments applied in 2000 in one 'Bing' block is encouraging; it may prove possible to permanently shift the vegetative/reproductive balance in young sweet cherry trees if precocity can be induced with Ethrel.

The absence of effects on fruit size the next year suggests that there are no negative carryover effects from Ethrel use for stimulation of flowering.

ReTain application to sweet cherries just prior to harvest does not appear to produce much in the way of useful effects. This may be no surprise since sweet cherry is not a climacteric fruit and does not naturally produce ethylene. ReTain-treated fruit became looser and lost firmness to the same extent as untreated fruit. Using Ethrel after ReTain application resulted in both loosening and reduction in flesh firmness, just as for Ethrel alone. Since ReTain blocks ethylene biosynthesis, application of ethylene via Ethrel should theoretically bypass any ReTain effect, which appears in fact to be the case.

Curiously, different Ethrel rates had little effect on fruit loosening in 2002, whereas rate effects were very clear in 2001. A double application of 1.5 pt/acre was equivalent in terms of fruit loosening and flesh firmness loss to a single application of 3 pt/acre. A single application of Ethrel at 4 pt/acre produced the same effects as the 3-pt/acre application. The temperature regime shortly after application may have a significant effect on the behavior of Ethrel. This aspect needs further study. Applying Ethrel closer to harvest did not improve loosening. The fruit loosening process in sweet cherry requires time and can be accelerated with Ethrel; therefore, the longer the period between Ethrel application and harvest, the looser the fruit will be. Concentrating the Ethrel in water did not alter its effects when it was applied at the same per-acre rate.

Acknowledgments:
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Budget:
Project Title: Bioregulator Uses for Vigor Management, Stimulating Cropping and Facilitating Mechanical Harvesting in Sweet Cherry
PI: Don C. Elfving, Horticulturist
Project duration: three years (2001-2003)
Current year: 2003
Project total (3 years): $40,520
Current year request: $16,280

Year	Year 1 (2001)	Year 2 (2002)	Year 3 (2003)
Total	**7,500**	**16,740**	**16,280**

Current year breakdown

Item	Year 1 (2001)	Year 2 (2002)	Year 3 (2003)
Salaries (Technical)[1]		6,000	**7,000**
Benefits (28%)		1,680	**1,960**
Wages (time-slip)[1]		3,500	**2,000**
Benefits (16%)		560	**320**
Equipment		1,000	**0**
Supplies[2]		1,000	**1,500**
Travel[3]		2,500	**3,000**
Miscellaneous		500	**500**
Total	**7,500**	**16,740**	**16,280**

[1]Technical and time-slip help is essential to put out the large number of treatments and collect the volume of data needed to evaluate growth, flowering, fruiting, fruit loosening and fruit quality responses to bioregulators.

[2]This category includes a variety of miscellaneous supplies, non-capital equipment, consumables, etc. that are needed to carry out the many trials in this research project.

[3]Treatment application and frequent data collection in distant sites, e.g., Pasco, Prosser, Zillah, Quincy, Cashmere, Orondo, etc. Includes vehicle lease-to-purchase, operating, repair costs.

CONTINUING PROJECT REPORT **YEAR 2/3**
WTFRC Project # CH02202 **WSU Project #3298**

Project Title: Induction of Branches (Feathers) in Sweet Cherry Trees in the Nursery and Orchard

PI: Don C. Elfving, Horticulturist
Organization: WSU Tree Fruit Research and Extension Center, Wenatchee, WA

Cooperators: Matthew D. Whiting, Assistant Horticulturist, WSU-IAREC, Prosser, WA
Dwayne Visser, Agricultural Research Technologist II, WSU-TFREC, Wenatchee, WA

Objectives: Fourteen trials were initiated in 2002 to test effects of cyclanilide on stimulation of lateral branch development in sweet cherry trees. Four tests were initiated in March 2002, while trees were still dormant. Five trials were initiated when bud development had reached the green-tip stage (April), two trials were begun in May soon after shoot growth began, two more trials were put on in June after significant new shoot growth had taken place, and one trial was begun in the nursery in early July. The early season trials had the objective of determining whether cyclanilide could be used to stimulate branch development from pre-existing buds on last year's shoots or on older wood. The in-season and nursery trials were primarily focused on the stimulation of branching from newly formed buds on current season's shoots.

Significant Findings:
Shoot growth is still underway as this is written (late August); therefore, final assessments of shoot growth effects are not yet available. General observations are reported below.

a. Dormant applications
Applications of cyclanilide alone or cyclanilide plus Promalin® in 50% v/v interior latex paint were made as bands painted onto the lower portions of unpruned, last year's shoots at concentrations of up to 5000 mg a.i./liter cyclanilide and 500 mg a.i./liter Promalin to assess if lateral shoot development could be stimulated from treated buds. Treatments were made to 2-year-old trees of 'Bing' and 'Rainier'/Mazzard in Pasco and East Wenatchee. Preliminary assessments indicate no effects of any of the treatments on stimulation of lateral branch development on the lower portion of the shoots.

b. Green-tip applications
Applications of cyclanilide at up to 1000 mg a.i./liter alone or combined with Promalin (500 mg a.i./liter) in 50% v/v interior latex paint were made to individual buds with or without notching or applied as mid-shoot bands with a brush. Treatments were made to 2-year-old 'Bing' and 'Rainier'/Mazzard trees and to 1-year-old 'Sweetheart'/Mazzard trees in Quincy and East Wenatchee, WA. Notching did induce some buds to develop into branches. Preliminary observations suggest that chemical treatments did not stimulate lateral shoot development in any cultivar, either when applied alone or combined with notching.

c. Early season applications
Cyclanilide at up to 100 mg a.i./liter with or without Promalin (500 mg a.i./liter) was sprayed onto the lower halves of last year's leader shoot using a backpack sprayer at the beginning of May, when shoot growth had just begun. Applications were made to2-year-old 'Bing'/Mazzard and 1-year-old 'Sweetheart'/Mazzard trees. Preliminary observations suggest no effects of these treatments on lateral branch development.

d. In-season applications
Cyclanilide at 50 or 100 mg a.i./liter with or without Promalin (500 mg a.i./liter), Promalin alone, or cyclanilide at 200 mg a.i./liter was applied to third-leaf 'Bing'/Mazzard trees when terminal shoots were approximately 27 cm in length. Promalin alone produced some lateral branch development from current season's buds on new shoots, but the branching was inconsistent from shoot to shoot. Cyclanilide alone at 50 or 100 mg a.i./liter also produced branching, but the branching effect was not uniform throughout the canopy. Mixing Promalin with cyclanilide appeared to considerably increase branch formation as well as uniformity of branching.

Cyclanilide at up to 100 mg a.i./liter with or without Promalin (250 mg a.i./liter) or Promalin alone was applied to third-leaf 'Sweetheart'/Mazzard trees with the objective of stimulating lateral branching on older wood. The treatments were sprayed on older, spur-bearing wood with leaves when terminal shoots were approximately 19 cm in length. None of the treatments induced lateral branch development from spur buds. Treatment with cyclanilide alone caused some phytotoxicity and defoliation in the treated area; when cyclanilide was mixed with Promalin, no defoliation occurred.

e. Nursery applications
Cyclanilide at 50 or 100 mg a.i./liter with or without Promalin (250 mg a.i./liter) or Promalin alone was applied to nursery trees of 'Bing' and 'Lapins'/Mazzard in early July to induce feathering. The products were sprayed across the tops of the trees to treat the upper portion of the newly developing shoots. The results were similar to those in 2001. Cyclanilide induced some lateral branch formation, but the greatest amount of branching was produced by cyclanilide at 100 mg a.i./liter mixed with Promalin. Interestingly, some of the branches formed from buds that were located very near or at the shoot apex at the time of treatment as well as farther down in the tree. The branching response appeared to be better in 'Bing' than in 'Lapins.'

Results and Discussion
Cyclanilide appears to be effective for stimulation of branching only when shoot growth is active. It appears to act by temporarily reducing the growth of the shoot tip, thereby interrupting apical dominance and permitting lateral buds to grow out into shoots. No activity was observed on older buds, even when high concentrations of cyclanilide were painted onto buds at green-tip that had just been notched and in which the cyclanilide/paint solution was painted into the notching cuts.

In sweet cherry, the strongest and most uniform branching in these trials was obtained when cyclanilide was combined with Promalin. This observation is in agreement with the results observed from the first trials in 2001.

There may be varietal differences in branching response to cyclanilide; further trials with other cultivars are needed to clarify the effects of genetics on the response to cyclanilide treatment.

Acknowledgments:
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Budget:

Project Title: Induction of Branches (Feathers) in Sweet Cherry Trees in the Nursery and Orchard

PI: Don C. Elfving, Horticulturist

Project duration: three years.

Current year: 2002-2003

Project total (3 years) $26,488

Current year request: $8,380

Year	Year 1 (2002)	Year 2 (2003)	Year 3 (2004)
Total	**8,288**	**8,380**	**9,820**

Current year breakdown

Item	Year 1 (2002)	Year 2 (2003)	Year 3 (2004)
Salaries (Technical)[1]	3,100	**4,000**	4,500
Benefits (28%)	868	**1,120**	1,260
Salaries (Time-slip)[1]	2,000	**1,000**	1,000
Benefits (16%)	320	**160**	160
Equipment	0	**0**	0
Supplies[2]	500	**800**	800
Travel[3]	1,000	**1,300**	1,600
Miscellaneous	500	**0**	500
Total	8,288	**8,380**	9,820

[1]Technical and time-slip help is essential to put out the large number of treatments and collect the volume of data needed to evaluate growth, flowering, fruiting, fruit loosening and fruit quality responses to bioregulators.

[2]This category includes a variety of miscellaneous supplies, non-capital equipment, consumables, etc. that are needed to carry out the many trials in this research project.

[3]Treatment application and frequent data collection in distant sites, e.g., Pasco, Quincy, Cashmere, etc. Includes vehicle lease-to-purchase, operating, repair costs.

FINAL REPORT

Project title: Preliminary studies on the biology and control of powdery mildew

PI: Robert A.Spotts
Organization: OSU Mid-Columbia Agricultural Research and Ext. Ctr.

Cooperator: Gary Grove, WSU

Objectives: Determine when fruit infection occurs in relation to maturity, evaluate the Gubler-Thomas model, and study the relationship between powdery mildew infection and pitting.

Significant findings:

- Fruit infection of Sweetheart occurred throughout late April, May, and June. Infection may occur prior to shuck fall and before mildew is observed.
- Infection of Lapins fruit occurred until fruit reached 12.5% soluble solids, but no clear relationship was observed for Sweetheart fruit.
- Mildew control on Bing leaves and fruit was similar with both the Gubler-Thomas (GT) and traditional spray programs. The traditional program required 3 sprays while the GT required 4.
- For Bing fruit, incidence of slight pitting was greater on nonmildewed fruit, but incidence of moderate pitting was greater on mildewed fruit. Mildew-infected Sweetheart fruit were not more likely to get pitted, either slightly or moderately, than nonmildewed fruit.
- Scholar (fludioxonil) reduced the severity of mildew on fruit treated postharvest.

Methods:

Time of infection of sweetheart fruit.

Tyvak bags were used to cover fruit and exclude mildew spores from April 23 (petal fall) to July 19 (harvest). Bags were moved weekly to a new set of fruit on 10 trees. Incidence and severity of mildew infection of fruit was determined at harvest.

Effect of fruit maturity on resistance to mildew infection.

Lapins and Sweetheart fruit were inoculated weekly from June 6 to June 28 with mildew spores, and soluble solids were measured on each inoculation date. Mildew incidence was determined at harvest.

Evaluation of the Gubler-Thomas model for spray timing.

A spray schedule based on the GT model was compared with one based on the traditional schedule of shuck fall, fruit fly spray, and preharvest. Four replicate Bing trees were sprayed based on each schedule, and unsprayed trees served as the control. Mildew infection of leaves and fruit was evaluated at harvest on July 5th.

Effect of mildew on pitting.

Healthy fruit and fruit with a light infection of mildew from studies 1 and 3 were bruised under standardized conditions and pitting evaluated.

Postharvest control of mildew with fludioxonil (Scholar).

Mildew-infected Lapins fruit were dipped in Scholar at 12 oz per 100 gallons. Control fruit were not treated. Appearance of mildew on the fruit was observed after 15 days storage at 32 degrees F.

Results and discussion:

1. Time of infection of sweetheart fruit (Table 1).

   From April 23 (petal fall) to July 2 (15% soluble solids), 6 out of 10 weekly protection periods reduced infected fruit by over 10%. These six periods were scattered throughout the 10 weeks, indicating that fruit were being infected constantly. Bagging from April 30 to May 21, prior to detection of mildew, reduced infection in three of the four weeks. From these preliminary results, it appears that fruit infection occurs constantly throughout late April, May, and June. Infection may occur prior to shuck fall and before mildew is observed**.**

2. Effect of fruit maturity on resistance to mildew infection (Table 2).

   Infection of Lapins fruit occurred until fruit reached 12.5% soluble solids on June 20. No clear relationship was observed for Sweetheart fruit. Additional, replicated studies will be necessary to establish reliable relationships between resistance to mildew and fruit maturity. Since resistance in Bing is thought to occur at about 15 brix, it appears that the relationship between fruit maturity and resistance to powdery mildew may vary with cultivar.

3. Evaluation of the Gubler-Thomas model for spray timing (Table 3).

   Mildew control on Bing leaves and fruit was similar with both spray programs and was about half of the incidence as on unsprayed leaves. Similarly, there was no difference between the incidence of fruit infected with mildew in the two programs, and both programs gave good control. The traditional program required 3 sprays while the model required 4.

   These results are similar to the previous 3 years. In 3 of the 4 years, the model required 4 sprays vs. 3 with the traditional program. The model was designed for grape mildew and will require “fine tuning” to be specific for cherry mildew.

4. Effect of mildew on pitting (Tables 4 and 5).

   For Bing fruit, incidence of slight pitting was greater on nonmildewed fruit, but incidence of moderate pitting was greater on mildewed fruit when the bruise was made in the infected tissue. When healthy tissue was bruised, no difference in pitting was observed between mildewed and healthy fruit. Mildew-infected Sweetheart fruit were not more likely to get pitted, either slightly or moderately, than nonmildewed fruit.

   These results agree with 2001 data for Bing. The relationship between mildew and pitting may vary with cultivar and needs further study.

5. Postharvest control of mildew with fludioxonil (Scholar).

   Signs of mildew (appearance of mildew on the fruit surface) were less on fruit treated with Scholar than on control fruit. The mildew, however was still visible on treated and control fruit. Thus, the Scholar appeared to suppress but not completely eradicate mildew from fruit. These are preliminary results based on a small number of fruit.

Table 1. Protection periods for reducing fruit infection caused by cherry powdery mildew, The Dalles, 2002			
Protection period	% mildew	Brix	Comments
4/23-4/30	85		petal fall
4/30-5/7	**76**		
5/7-5/14	**62**		shuck fall
5/14-5/21	**64**		mildew?
5/21-5/28	83		mildew present
5/28-6/4	**76**		
6/4-6/11	**79**		
6/11-6/18	92		
6/18-6/25	88	11.7	
6/25-7/2	**71**	12.6	
7/2-7/9	80	15.1	
7/9-7/19	**59**	15.8	
No protection	89	21.2	Harvest 7/19

Table 2. Resistance of cherry fruit to infection with powdery mildew, Hood River, 2002			
Cultivar	Inoculation date	% mildew	Brix
Lapins	June 6	7.8	8.6
	June 13	4.0	9
	June 20	1.2	12.5
	June 28	0.0	12.5
	Noninoculated	1.1	N/A
Sweetheart	June 6	5.4	7.5
	June 13	4.8	8.2
	June 20	2.7	8.5
	June 28	4.6	12.4
	Noninoculated	0.0	N/A

Table 3. Evaluation of Gubler-Thomas model for cherry mildew (Bing), MCAREC, 2002			
		Mildew incidence (%)	
Schedule	# sprays	Leaves	Fruit
GT	4	22.5a	2.3a
Traditional	3	25.7a	2.3a
Unsprayed	0	40.7a	6.8b
GT sprays: 5/8 Omni oil; 5/23 sulfur; June 11 and 25 Rally. Traditional sprays 5/8 Omni oil (Shuck fall; 6/3 sulfur (fruit fly); 6/28 Rally (preharvest) Harvest on 7/5.			

Table 4. Effect of powdery mildew fruit infection on pitting, 2002				
	Percent of fruit pitted			
Mildew	Mildew-infected tissue		Healthy tissue	
status	Slight	Moderate	Slight	Moderate
Light	58a	37a	70a	30a
None	92b	7b	73a	27a
Bing fruit from MCAREC				

Table 5. Effect of fruit powdery mildew infection on pitting of Sweetheart fruit, The Dalles, 2002		
Mildew	Percent fruit pitted	
status	Slight	Moderate
Light	89a	11a
None	86a	14a

CONTINUING PROJECT REPORT **YEAR 3/3**
WTFRC Project #: 13C-3361-4795

Project Title: Epidemiology and control of powdery mildew of cherries

PI: G. G. Grove, Plant Pathology, WSU- IAREC, Prosser, WA

Co-investigator: R.A. Spotts**,** Plant Pathologist, Oregon State University, Hood River, OR

Cooperators: Clyde Fraisse, Biological Systems Engineer, WSU-IAREC, Prosser, WA
C.L. Xiao, Plant Pathologist, WSU-TFREC, Wenatchee, WA
Tom Auvil, Horticulturist, WTFRC, Wenatchee
Matt Whiting, Horticulturist, WSU-IAREC, Prosser, WA

Objectives:

• Determine if irrigation management can be used to delay the onset of cherry mildew epidemics and/or reduce disease severity.

• Continue large plot (on-farm) testing of oil-based weather driven cherry powdery mildew management program.

• Continue implementation of the phenology based spray oil program for cherry powdery mildew.

• Investigate the influence of weather variables and current irrigation practices on aerial conidia populations of conidia of the cherry mildew fungus.

• Continue field evaluations of various "soft" fungicides for efficacy against stone fruit mildews and as components of antiresistance strategies for maintaining the effectiveness of "at risk" fungicides.

• Evaluate new and novel spray technologies for mildew management on Bing, Rainer, and Sweetheart cherries.

• Using high efficiency air samplers, devise a means to detect the vineyard presence of *P. clandestina* very early in the process of a powdery mildew epidemic.

• Develop baseline sensitivities of *P. clandestina* isolates to various DMI and strobilurin fungicides.

• Develop a *P. clandestina* -specific temperature algorithm for the Gubler-Thomas Powdery Mildew Model.

Significant findings:

- Delaying the initial irrigation had significant effects on sucker quantity and length, fruit soluble solids, fruit weight, and size class. However, the only significant differences were observed in the treatment where the initial water application was delayed the longest.

- Powdery mildew epidemics commenced with the initial irrigation set in Prosser, Crescent Bar, Malaga, and Stemilt Hill orchards. Mildew symptoms appeared 5-7 days after the initial irrigation set was applied.

- Timing the initial fungicide application according to initial irrigation or initial appearance of symptoms resulted in mildew control superior to phenology based sprays

- Good powdery mildew control was attained using programs containing $\leq$ 2 applications of DMI and/or strobilurin fungicides. Trials were conducted in orchards under moderate and extreme disease pressures.

- Quinoxyfen, petroleum oils, and neem oil, applied alone or in combination, provided mildew controls superior to that obtained using DMI fungicides.

- Full fruiting season (shuck fall-harvest) oil applications had deleterious effects on fruit "sheen" and surface scarring but had no effect on fruit soluble solids, firmness, or weight. Sheen and surface scarring was insignificant when oil applications were terminated at pit hardening.

- In order document the nature and extent of fungicide resistance and to monitor baseline sensitivities of *P. clandestina* to new fungicides, numerous isolates were collected from orchards in North Central Washington, Pasco, Yakima, Prosser, and The Dalles. A technique was developed for long-term maintenance of cultures.

- High spray gallonage significant reduced the severity of powdery mildew on 'Sweetheart' fruit. In terms of mildew management, spray gallonage was more important than fungicide concentration.

- Postharvest applications of Apogee and Ethrel had no effect of postharvest shoot growth.

New and/or expanded research initiatives:

- Extraction of DNA from *P. clandestina* was accomplished using commercial DNA extraction kits. The technique is being adapted to identify cherry powdery mildew in a mixed fungal population trapped from the orchard air using high-efficiency air samplers.

- A research orchard designed specifically for irrigation studies was established at the WSU-IAREC Roza farm.

- Weather stations designed to facilitate the development of the cherry disease forecasting component of the WSU-CPAS AWN Weather Network were established at the WSU-Roza farm.

Methods:

Continue developing practical fungicide resistance management strategies. Various combinations and rotations of DMI, quinoline, strobilurin, SAR, oil, and sulfur compounds will be applied to Bing, Rainier, Van, Lapins, and Sweetheart cherries and evaluated for efficacy and phytotoxicity. Compounds will be applied in calendar and weather based management programs. Disease incidence and severity will be determined by randomly selecting five terminal shoots from each plot, and picking five leaves from each terminal starting with the last fully open leaf and working down the shoot for a total of 25 leaves per plot. The percentage of the surface area of the underside of each leaf infected by mildew will be estimated and recorded. Data will be subjected to analysis of variance and means separated according to Fisher's PLSD at $P < 0.05$.

Irrigation studies. Investigations will be continued by delaying irrigation in portions of a cherry orchard with a history of severe powdery mildew. Foliage produced on or near bark fissures will be periodically inspected with a hand lens in order to ascertain the timing of primary infection. Several weeks later, disease incidence and severity will be determined by randomly selecting 10 terminal

shoots on each tree and determining the percent leaf area colonized on each of ten leaves beginning at the first fully expanded leaf beneath the shoot apex. Data will be subjected to analysis of variance and means separated according to Fischer's Protected LSD at $P < 0.05$. For long term studies of the effects of irrigation type and duration on primary infection, secondary infection, and overall disease pressure, an orchard consisting of drip, micro sprinkler, and under tree impact sprinklers will be established at WSU-IAREC. The effect of irrigation type on orchard microclimate and airborne spore concentrations will be studied using CR-21X Dataloggers and volumetric spore traps.

Sprayer Technology. Mildew control using electrostatic, curtain, and conventional sprayers will be evaluated in Wenatchee, Pasco, and Prosser orchards with histories of powdery mildew. Conventional spray technology will serve as controls. Replicated trials comparing mildew control using curtain, electrostatic, and conventional airblast equipment will be conducted in Prosser.

Forecasting and early detection. Continue development of oil-based phenology and symptom/weather/irrigation-driven cherry mildew management program. Wenatchee, Yakima, and Pasco orchards with histories of repeated powdery mildew epidemics will be used for this portion of the study. Portions of orchards will be treated using conventional spray programs while separate portions will be treated using the oil programs. Foliar disease incidence and severity at harvest will be determined as described previously.

Isolates of *P. clandestina* will be collected from multiple orchards in Eastern Washington. Infected young leaves will be removed from plants in the early-morning hours, placed in cooled plastic containers, and transported to laboratory. In order to maintain and collect specific isolates, horsehair attached to a needle probe will be used to transfer single conidial chains to cherry leaf disks or plantlets. Infected plant material and isolates will be maintained in a Burkhard micro propagation chamber. DNA of various isolates will be collected from conidia and mycelia using previously described techniques. *P. clandestina* DNA will also be obtained from researchers throughout the world. Other airborne fungi common in the vineyard air will be collected using a Burkard depositional air sampler. Fungi will be isolated and maintained in pure culture. In order to determine specificity, primers developed for *P. clandestina* will be tested for cross reaction to other powdery mildew mildews and unrelated airborne fungi.

Using leaf disk techniques developed by W.D. Gubler for studies of grape powdery mildew, isolates of *P. clandestina* will also be assayed for their sensitivity to DMI and strobilurin fungicides. Wild type and 'extended exposure' isolates will be assayed.

Results and Discussion

Management of cherry mildew was improved by timing the initial fungicide application when either 1) the first irrigation was applied or 2) the first signs of powdery mildew appeared provided resulted in a significant reduction of mildew severity (Table 1). In several cases this improvement was obtained using no DMI or strobilurin fungicides. Oil applications were limited to no later than pit hardening. A potential shortfall in sulfur treatments was the requirement for a short (7-10 day) spray interval.

In all experimental sites, powdery mildew symptoms and signs appeared 7-10 days after the initial irrigation set, provided that temperatures $\geq$ 50 F during watering (Table 2). We conclude that in the absence of significant spring rains, irrigation practices profoundly influence the onset of powdery mildew epidemics.

The rational for delaying the initial irrigation set was to postpone primary infection in order to shift the explosive phase of cherry mildew epidemics after harvest. In our trial, delaying the initial irrigation > 2weeks reduced powdery mildew severity (Table 3). However, mildew pressure during 2002 was low in the test orchard. Irrigation delays of 0-6 weeks also had significant effects on fruit soluble solids, fruit weight, sucker length, sucker number, fruit size, and leaf area (Tables 4,5).

Harpin protein and biological compounds failed to adequately control powdery mildew, indicating that a "stand-alone" fit for these compounds for mildew management is not probable. Further testing may reveal more appropriate fits in chemical spray programs. Harpin protein had no effect on fruit size, marketable yield, plot weight, and fruit firmness.

Infection of 'Sweetheart' fruit by *P. clandestina* was best managed by using 400 gallons of water per acre. A 1x fungicide rate at 400 GPA provided mildew resulted in fruit losses lower than losses attained using 1x/200 GPA, 1x/50 GPA, 4x/100 GPA, 2x/100 GPA, and 0.5x/200 GPA (Table 6).

Table 1. Severity of cherry powdery mildew when timing the initial fungicide application according to the initial appearance of symptoms (FS), initial irrigation (FI), or phenology, Wenatchee, WA 2002. Means followed by common letters are not significantly different according to Fischer's Protected LSD ($P = 0.05$).

Treatment	**Disease severity**
Stylet Oil (FI), then Microthiol (7 days)	7.1 c
Stylet Oil (FS), then Microthiol (7 days)	8.1 bc
Stylet Oil (FI), then Microthiol (10 days)	8.2 bc
Stylet Oil (FS), then Topsin/Abound (14 days)	8.4 bc
Industry Standard	8.9 ab
Control	10 a

Table 2. Initial visual detection of powdery mildew symptoms and signs in sweet cherry orchards in Eastern Washington. Temperatures listed are the average over the length of the irrigation set.

Location	**Initial Irrigation**	**Temperature**	**First Symptoms**
Crescent Bar	4/22	56 F	4/29
Malaga	5/6	66 F	5/14
Prosser	4/23	60 F	4/30
Stemilt Hill	5/28	66 F	6/7

Table 3. Cherry powdery mildew severity in a Pasco, WA cherry orchard where the initial irrigation set was delayed 0-6 weeks.

Irrigation Delay	**Mildew severity**
None	1.29 a
2 weeks	1.24 a
4 weeks	0.67 b
6 weeks	0.36 b

Table 4. Fruit weight, fruit soluble solids, and sucker length, in a Pasco, WA cherry orchard where the initial irrigation set was delayed 1-3 weeks.

Irrigation Delay	Weight (g/cherry)	Soluble solids	Change in Sucker length	Sucker Number	Leaf area (cm2)
Normal	10.7 a	17.7 b	8.8 a	11.7 ab	665.7 a
2 week	10.6 a	18.6 b	6.6 ab	16.7 a	658.9 a
4 weeks	10.4 a	18.0 b	6.5 ab	16.0 a	649.5 a
6 weeks	9.3 b	21.4 a	4.4 b	7.9 b	513.3 b

Table 5. Percentage of <9 row cherries in a Pasco, WA cherry orchard where the initial irrigation set was delayed 0-6 weeks. Raw and transformed data are presented.

Irrigation Delay	Percent < 9 row cherries
None	24.0 a
2 week	15.5 a
4 weeks	15.0 a
6 weeks	0 b

Table 6. Influence of fungicide rate and spray gallonage on powdery mildew of 'Sweetheart" cherries, Wenatchee, WA 2002. An Abound, Rally, Procure, Flint, and Kaligreen fungicide alternation was used in all treatments.

Gallonage	Fungicide Rate	Mildew Incidence (%)
Control	Control	64.0 a
100	1x	25.0 a
100	0.5 x	19 a
100	2x	13.0 b
100	4x	9.5 b
50	1x	23.5 a
200	1x	21.0 a
400	1x	7.0 b

Budget:

Title: Epidemiology and control of powdery mildews of cherries

Principal investigator: Gary Grove

Project duration: 3 years

Project total (3 years); $132,131

Current year request: $41,852

Salaries	2001-2002	2002-2003	**2003-2004**
Jeff Lunden, Research Associate (0.25)	$12,750	$12,636	**$12,636**
Timeslip Labor	$12,200	$12,200	**$12,200**
Benefits			
Lunden	$10,117	$3,664	**$3,664**
Timeslip	$1,960	$1,952	**$1,952**
Service and supplies (chemicals, glassware)	$6,700	$6,700	**$6,700**
Travel*	$4,700*	$4,700*	**$4,700***
Totals:	$48,427	$41,852**	**$41,852**

* Project will involved plot work in Chelan, Franklin, Benton, Grant, and Yakima Counties

**Funded at $47,120 for 2002.

CONTINING PROJECT REPORT **YEAR 3/3**
WTFRC PROJECT #: CH-01-14 **ORGANIZATION PROJECT #: 13C-3361-5291**

PROJECT TITLE: Protecting Pacific Northwest cherry orchards from serious virus threats.

PI: Ken Eastwell, Associate Plant Pathologist
Washington State University – IAREC, Prosser
CO-PI'S: Bill Howell, Manager Nrsp-5, Wsu-Prosser
COOPERATORS: Various growers

PROJECT OBJECTIVES:

1. Develop a strategy to control the rapid decline of cherry trees associated with *Cherry leaf roll nepovirus* (CLRV).
FY2003:
a) Determine transmission mechanisms for CLRV in orchards of the Pacific Northwest.
b) Initiate small-scale trial to determine symptoms of CLRV on new and promising cherry cultivars.

2. Determine the biology of virus diseases of concern to cherry production in Pacific Northwest.
FY2003:
a) Develop diagnostic capabilities suitable for monitoring little cherry viruses in orchards of the northwest.

SIGNIFICANT FINDINGS:

Project Objective 1:

- A rapid decline of cherry trees in the Pacific Northwest is induced by an isolate of *Cherry leaf roll virus* (CLRV) in combination with one or more of the *Ilarviruses* that are common in all cherry production areas (i.e., *Prunus necrotic ringspot* and *Prune dwarf ilarviruses*).
- CLRV is present in the Yakima Valley and the lower portion of the Columbia River basin. A limited survey reveals no occurrence of CLRV in the mid-Columbia basin.
- Although there are exceptions, most infection sites consist of 1 to 5 infected trees.
- Most trees exhibiting significant CLRV-induced decline are 12 to 25 years old.
- No CLRV is detected in registered mother trees in nurseries participating in the Washington certification program.
- CLRV is pollen-borne. This does not necessarily mean that the virus is pollen transmitted.

Project Objective 2:

- A virus-associated disease appeared in the mid-Columbia Basin. The disease spread rapidly. A virus isolated from diseased tissue was partially characterized and appears to be a previously unknown virus.
  - We developed a laboratory test to detect infected trees.
  - Aggressive tree removal by the grower has contained the virus. We are routinely testing trees at the site to confirm.
- A virus related to *Little cherry virus-1* has been identified in several orchards of Washington State. This is significant because, unlike the virus commonly found in western North America, the means by which *Little cherry virus-1* spreads in the orchard is unknown.

RESULTS AND DISCUSSION:

Cherry production underwent an ambitious revitalization program during the early 1950's. To restore productivity of an ailing industry, trees affected with virus-like diseases were removed throughout the Northwest cherry growing districts. With the advent of certification programs in the early sixties, the

incidence of virus diseases abated significantly. However, the emergence of new viruses and the resulting reduction in yield continues to challenge the profitability of cherry production.

Objective 1: Many fieldmen and growers have contacted us for assistance. Faced with reduced profitability from an increasing number of diseased trees in their orchards, they sought guidance for identification and corrective measures to minimize the economic impact. With reliable testing strategies developed by us over the past two years, the cause of unproductive or declining trees could be related, in many cases, to infection by CLRV. Through this interactive process, many new sites of infection were identified this season. New sites were also discovered through an informal "drive-by" survey of many orchards. Based on our experience, approximately one-third of known infections sites are visible from public roads.

Although direct evidence is not yet available, the disease associated with this virus appears to be spreading. We established six plots in three grower blocks where CLRV was known to occur. Each tree in the plots was sampled and tested for CLRV, *Prunus necrotic ringspot virus* and *Prune dwarf virus*. The testing process will be repeated annually to monitor the dispersal, if any, of virus infection within the orchard environment.

The mechanism by which the disease is spreading remains unclear. However, the pattern seen in the distribution of infected trees has been very distinctive. An initial infection develops in an orchard, potentially several miles from any known source of infection or other cherry trees. Once established, disease radiates outward slowly from the initial infection site to infect adjacent trees. Initially, only one or two shoots of the adjacent trees will express symptoms before all of the major scaffold limbs are involved.

CLRV belongs to a group of viruses that are typically transmitted by pollen and/or by nematodes. We have looked for but not found any evidence of nematode transmission of CLRV. Indeed, the erratic spread of disease that has become apparent in Washington State is not consistent with a soil-borne vector. Therefore, emphasis has been placed on the association of pollen with virus dissemination.

CLRV is associated with pollen in high concentration. We have confirmed this by serological tests of pollen extracts. Moreover, the virus associated with the pollen is infectious. Rubbing the surface of host plants with dried pollen reliably establishes virus infection in test plants. However, the role of pollen in virus transmission in the orchard setting is unknown. Thrips are pollen-feeding insects that have been implicated in the transmission of other pollen-borne viruses. Very preliminary data suggests that the combination of thrips and pollen from infected cherry trees is a factor in the transmission of CLRV to experimental hosts. This work needs to be continued to determine if thrips-mediated transmission from pollen to cherry plants occurs.

Possible pollen transmission is an important issue that must be resolved. Effective and appropriate measures to control the spread of this virus require knowledge of the spread mechanism. If pollen transmission occurs, then growers would adopt a strategy suitable to reduce further spread of the virus to adjacent trees and throughout the industry.

The virus that we have isolated from diseased cherry trees has been identified as CLRV based on serological and molecular data. Despite its name, CLRV has an extensive natural host range, with specific isolates infecting each host. Indeed, CLRV is primarily recognized as a virus problem in walnuts and hardwood forests of central Europe. No data are available regarding the isolate of CLRV that we have obtained from cherry trees, other than the fact that it reacts with antiserum produced against the cherry isolate in Europe. We currently do not know if the virus in our area represents a

mixture of different strains that vary in disease severity. It is prudent to obtain baseline characteristics of the virus that we have detected and isolated from trees of the Northwest.

Objective 2: A virus in a sweet cherry orchard of Central Washington emerged. The devastating disease associated with this virus spread rapidly culminating in the removal of more than 170 mature fruiting trees. We developed a laboratory test for this previously undescribed virus. It now seems that the course of rigorous and aggressive tree removal followed by the grower was adequate to delimit the virus infection. Testing of trees around the infection site and randomly through the orchard and adjacent properties did not reveal any new infections during the past two years. Continued monitoring is essential to determine the potential long-term impact of this virus and the ability to contain the infection by an uncompromising tree removal campaign.

Little cherry is a disease that seriously impacts fruit quality. This disease was widespread in western North America from 1930 to 1960. A virus that is transmitted by the apple mealybug causes this disease. Control of apple mealybug through modifications of orchard fauna and changes in horticultural practices has greatly diminished the annual losses to little cherry disease and the occurrence of new infections. In the early 1990's, little cherry disease appeared in central Germany and spread rapidly through a cherry production area, with 1200 new infections reported in one year (Harms *et al.*, 1996). This rapid expansion of infection was occurring in the apparent absence of mealybug (Büttner *et al.,* 1994). Although the symptoms are very similar to the disease that had appeared in North America, modern molecular techniques reveal that the viruses that cause little cherry disease in Europe and North America are very distinct. The cause of little cherry disease in Europe is now known as *Little cherry virus-1*, while the mealybug-transmitted virus predominant in North America is *Little cherry virus-3*. The presence of *Little cherry virus-1* was confirmed for the first time in several cherry orchards in the northwest. This finding is significant because that insect vector of *Little cherry virus-1* is unknown making it impossible to develop control strategies.

Clearly, viruses are not involved in every case of orchard decline. However, it is important to recognize when viruses induce or contribute to tree decline or reduced orchard income. The research in this proposal will investigate the viruses associated with the decline of cherry orchards in the Northwest and develop appropriate disease control measures for commercial growers.

METHODS:

Objective 1a) Determine transmission mechanisms for CLRV in orchards of the Pacific Northwest.

Nematode transmission is the primary method of virus spread for many of the viruses that belong to the same group of viruses as CLRV. A potential vector, *Xiphinema revesi*, was identified in several of the orchards where CLRV occurs and appears to have spread. Successful maintenance of this nematode in greenhouse studies has been elusive for us and other researchers in North America; therefore field studies are the best option for investigating this potential. It was demonstrated that CLRV moves very slowly or not at all through 'Colt' rootstock (Rowhani & Mircetich, 1992). To evaluate the influence of rootstock on CLRV transmission, we planted 25 'Bing' on 'Colt' and 25 'Bing' on 'Mazzard' in orchards that were mapped for CLRV. In all cases, the replants survived their first full growing season. They were tested this spring and all young trees have remained free of CLRV. The disease status of these trees will be monitored over the next several years to see if they become infected, and if there is a difference between the rate at which trees on 'Mazzard' versus 'Colt' rootstock become infected. If CLRV is transmitted exclusively through the soil, then trees on 'Colt' rootstock should remain healthy.

CLRV occurs in pollen grains from infected trees (Massalski & Cooper, 1984; plus our observations). It is possible that pollen plays a role in transmission. The possibility of pollen transmission will be determined through continued observation and testing of healthy non-infected maternal trees flanked

by CLRV-infected pollinizers, and in greenhouse studies with pollen collected from infected trees. The pollen is collected and dusted onto leaves of cherry seedlings either in the presence or absence of Western flower thrips. Since the inoculation process by an insect generally introduces a very small amount of pollen, observation must continue for longer periods to allow the virus titer to build up to detectable levels. Therefore the seedlings will be maintained in the greenhouse and lath house for an entire growing season and will be tested for CLRV the following spring.

Objective 1b) Initiate small-scale trial to determine acute symptoms of *Cherry leaf roll virus* on new and promising cherry cultivars. Most of the trees known to be infected with CLRV (>95%) are between the ages of 12 and 25 years. Because of this age distribution, we have only observed the impact of CLRV on the sweet cherry cultivars 'Bing', 'Van' and 'Chinook'. We propose to graft-inoculate trees of several of the new and promising sweet cherry cultivars such as 'Sweetheart', 'Tieton', 'Chelan' and 'Rainier'. At the end of the first growing season, the young trees will be inoculated with CLRV. The trees will be maintained in the greenhouse and lath house for two seasons for observation. A duplicate set of trees will be inoculated with CLRV plus a mixture of *Prunus necrotic ringspot* and *Prune dwarf viruses*.

Objective 2a) Develop diagnostic capabilities suitable for monitoring little cherry viruses in orchards of the northwest. Currently, there are no diagnostic methods to readily detect *Little cherry virus–1* in the orchard setting. We sequenced a portion of the genome and know that the *Little cherry virus-1* in the Pacific Northwest is a close relative of the one found in Europe, and yet distinct. This virus is known to spread in orchards in Germany (Harms *et al.*, 1996), and there is circumstantial evidence to suggest that it spreads in the Pacific Northwest as well. Other factors such as zinc deficiency or winter damage to the roots can promote little cherry-like symptoms. Therefore, it is important to quickly ascertain whether the small fruit size and off-color is the result of virus infection or abiotic factors. We have very few options at this time to assist growers in determining if this virus is the cause of poor production in their blocks. Currently available testing strategies are very costly. We propose to use this opportunity to develop a serological test that can be incorporated into routine virus testing programs. This would enable us to test trees for individual growers and provide information on the disease status of their trees quickly and in a cost effective manner.

LITERATURE CITED:

Büttner C, Jelkmann W, Graf H. 1994. Zum Auftrete der Kleinfrüchtigkeit der Süßkirche (little cherry disease) in deutschen Erwerbsobstanlagen. [The occurrence of little cherry disease in German commercial orchards.] Erwerbsobstbau 36:10-13.

Harms M, Büttner C, Graf H, Schickedanz F. 1996. Untersuchungen zur Ausbreitung der virösen Kleinfrüchtigkeit der Süßkirsche (Little cherry disease) in norddeutschen Erwerbsobstanlagen. [Investigations on little cherry disease expanding in sweet cherries of north German orchards.] Erwerbsobstbau 38:2-7.

Massalski PR, Cooper JI. 1984. The location of virus-like particles in the male gametophyte of birch, walnut and cherry naturally infected with cherry leaf roll virus and its relevance to vertical transmission of the virus. *Plant Pathology* 33:255-262.

Rowhani A, Mircetich. 1992. Mechanical transmission, susceptibility, and host response in Bing sweet cherry and three rootstocks by the walnut strain of Cherry leafroll virus. *Plant Disease* 76:264-266.

BUDGET REQUEST

PROJECT TITLE:	Protecting Pacific Northwest cherry orchards from serious virus threats.
PI:	Ken Eastwell, WSU-Prosser
PROJECT DURATION:	2001-2003
CURRENT YEAR:	2003
PROJECT TOTAL (3 YEARS):	$66,612
CURRENT YEAR REQUEST:	$26,612

ORIGINAL BUDGET REQUEST:

Year	Year 1 (2001)	Year 2 (2002)	**Year 3 (2003)**
TOTAL	22,040	25,465	**26,612**

CURRENT YEAR BREAKDOWN:

Item	Year 1 (2001)	Year 2 (2002)	**Year 3 (2003)**
SALARIES	9,465	12,012	**12,705**[1]
Benefits	2,744	4,084	**4,193**[2]
Wages	---	---	**---**
Benefits	---	---	**---**
Equipment	---	---	**---**
Supplies	7,791	3,904	**9,714**[3]
Travel	---	---	**---**
Miscellaneous	---	---	**---**
TOTAL	20,000	20,000	**26,612**[4]

1 Salaries: 0.35 FTE Associate in Research.

2 Benefits: 33% of salary

3 Supplies and services:

Objective 1**:**	
Greenhouse expenses (soil, pots, plants, fertilizer etc.)	$212
ELISA tests (400 tests at $6.38 each)	2,552
Characterization of CLRV (sequence determination & comparison)	1,500
Objective 2:	
Greenhouse costs (soil, plants, pots etc.)	$200
RT-PCR tests (150 samples at $10/sample - supplies only)	1,500
Production and isolation of virus coat protein	2,000
Antibody production	1,750
TOTAL SUPPLIES & SERVICES	**$9,714**

CONTINUING PROJECT REPORT **YEAR 3/3**
WTFRC Project # CH-01-13

Project title: Host and Feeding Preference of Cherry Fruit Fly

PI: Wee Yee
Organization: USDA-ARS, Wapato, WA

Objectives:
2001
- Determine cherry fruit fly activity within days and during the season.
- Relate fly abundance to larval infestation of fruit.
- Determine distances flown by the flies.

2002
- Determine host use patterns by flies in eastern and western Washington.
- Determine the preference of flies for different varieties of sweet and sour cherries and native hosts in the laboratory, and ...
- Developmental rates of flies in these different hosts.

2003
- Continue to monitor fly populations on sour and sweet cherries in eastern and western Washington and identify new hosts.
- Identify food sources of flies on different cherry hosts over the season in eastern and western Washington.
- Evaluate the food sources and preferences in the laboratory, with goal of incorporating foods in baits for control.

Significant findings:
2001
- Males on fruit, females equally on fruit and leaves; most active midday
- There was a poor relationship between flies detected and larval infestation of fruit.
- Flies dispersed readily from host trees, averaging 50 m after 2 weeks.

2002
- In eastern Washington, more flies were found on sour than sweet cherries.
- Relationship does not seem to be related to preference in the laboratory.
- Larval development in sour and sweet cherries is the same.
- In eastern Washington, there appears to be no native host, as choke cherries do not produce flies; flies preferred sweet cherries.
- In western Washington, sour and sweet cherries are less heavily infested than in eastern Washington. Birds attack these cherries before flies can finish development.
- In western Washington, bitter cherries are heavily infested into August and September.
- In western Washington, cascara is probably a new host of cherry fruit fly, pending positive identification at adult emergence.

Methods:
1. Fly numbers on 4-6 pairs of sour and sweet cherries will be determined throughout the season, as in 2002. In addition, fruit samples will be collected at bi-weekly basis from trees to determine larval infestations of fruit. Adult and larval numbers on bitter cherry and cascara in western Washington will also be determined weekly or bi-weekly to document their possible role in contributing to fly populations on cultivated cherries.
2. Choice experiments using whole branches with fruit from sour and sweet trees that had been held inside sleeves will be conducted.

3. To determine if substances on leaves and fruit can sustain longevity and fecundity and whether possible nutrients on them change over the season, branches with intact and damaged leaves and fruit will be removed from cultivated and native host trees throughout the season and brought into the laboratory, placed in containers with water (to keep them fresh) inside cages, and exposed to flies. Five groups of 10 field-collected male and female flies will be exposed to substrates. Observations will also be made to determine if a preference for fruit or leaves exists.
4. If the leaves and fruit do sustain survival, substances from them will be washed and the concentrates dried on plastic. Groups of 3-5 females and males will be exposed to the fruit and leaf concentrates and also to whole fruit and leaves to determine if a preference in foods and their form exists.

Results and Discussion:

The consistently greater numbers of flies seen and caught on four out of five sour 'Montmorency' cherry trees paired with sweet 'Bing' trees (spaced 0-6 m apart) (Fig. 1, data from only 4 trees shown) suggest the flies preferred sour cherries in the field. The similar infestation trends of cherry fruit flies on sour and sweet cherries were a reflection of the closeness in the developmental rate of the hosts. In both cherry species, flies were most abundant when fruit were ripe, which occurred at similar times (Fig. 1). While there was no preference for sour cherry fruit in the laboratory (Table 1), a preference for sour cherry trees in the field is possible, as detached fruit may not elicit natural responses. Flies may respond best to a combination of overall tree structure, shape, fruit color and number, and maybe volatiles emanating from fruit. Fruit on the sour cherry trees used in this study were more visible and seemingly more numerous because of the lighter foliage on sour trees. Volatile compounds from sour and sweet cherries differ substantially and differentially affect responses by the flies. The actual factors that caused the higher numbers to appear on sour cherries need to be determined as this may lead to new detection methods or trap designs. Another possibility to explain the field results is that the availability and quantity of preferred foods on sour and sweet cherries differed.

As an alternative to host preferences, the higher fly numbers seen and caught on sour cherries may have resulted from the sour cherry trees being smaller and sparser in foliage, and had little to do with actual abundance on trees. This perhaps made it easier for observers to see the flies and for the flies to see the traps.

The higher numbers on sour cherries also may be a result of sour cherries being retained longer, as this allowed more time for flies to infest and develop in the fruit. Aside from the naturally longer fruit retention, birds also were a key factor in determining the abundance of cherries on the trees, as they removed large numbers of sweet but not sour cherries from the trees. When this occurs in July, flies on sweet cherries may disperse to the sour cherries. While the high temperatures from early to mid July can be lethal to the flies, larval development can be completed within a few weeks in the sour cherries. Thus sour cherries can still produce larvae after sweet cherries have disappeared. Flies under sour cherry trees can emerge the following year and re-infest the sour cherries or may infest neighboring sweet cherries. If this is the case, sour cherries can serve as a large reservoir of flies in an otherwise low fly density yard.

Development of larvae inside sour and sweet fruit was not different (Table 2), despite the differences in their nutritional value. Perhaps the larvae inside fruit need only a minimum level of nutrients that are met by sweet cherries, beyond which there are no benefits.

Overall, a preference for sour cherries was not shown for certain. However, the results suggest that flies persist longer on sour cherry trees than on sweet trees because of the physiology of fruit development and the low fruit removal by birds. This may result in greater fly population buildup below sour cherry trees. This knowledge will benefit the cherry industry because it suggests sour cherry trees should be targeted for removal or management, as high populations on them may increase the threat of flies infesting commercial orchards.

Choke cherries clearly were not a good host for cherry fruit flies in the Yakima Valley, as none of the 14 trapped trees in 2001 and only 3 out of 26 trees in 2002 yielded flies (Fig. 2). In the 3 cases where flies were trapped, no infested fruit were found. Cherry fruit flies have been reared from choke cherries, but they have not been proven to be a natural host. Temperatures in the Yakima Valley are generally very hot when chokecherries ripen in July and August. During this time, sustained heat and not a lack of food probably kills the adults. Because of this, the presence of choke cherries in commercial growing districts almost certainly is not a threat to the cherry industry in the Yakima Valley. When given a choice of sour and sweet cherries in the laboratory, flies laid all their eggs into sweet cherries.

In contrast to choke cherries, bitter cherries were a relatively good host for cherry fruit flies in western Washington, as 5 of 7 trees in 2002 (thus far) yielded flies on traps (Fig. 2) and in fruit. Numbers in bitter cherries were higher than in seedling sweet cherries (Table 3, data being collected). Because the bitter cherries develop later than cultivated cherries, the first appearance of flies on bitter cherry between late July and August was expected. Although nearly all cultivated cherries in the western Washington study areas were stripped of fruit by birds just after they turned red, most bitter cherries were untouched. Bitter cherries can support flies late into the season probably because birds remove few larvae. Flies on bitter cherry may be a concern for cherry growers in the areas just west of Wenatchee and Yakima. Although most flies associated with bitter cherries emerge in August, the earlier-emerging bitter cherry flies can probably infest cultivated cherry trees that still have fruit in late July.

The later occurrence of flies on traps placed in non-cherry trees such as apples and hawthorn in western Washington did not indicate host usage, but it did indicate flies were able to survive in the absence of cherries, so foods must have been available on non-host trees. This allowed flies to persist late into the year. In Skamania County, the last cherry fruit fly was captured between 26 and 29 October 2001. This is the latest adults of this species has been shown to be active and suggests that under ideal conditions these flies can lay eggs into bitter cherries or even adapt to other hosts still fruiting late in the year.

The longer flight periods in western Washington compared with eastern Washington were almost certainly related to the lower temperatures and the later development of a larger variety of host fruit. Aside from bitter cherries, which were rare at the Skamania site, both hawthorn and cascara may contribute to the presence of flies late in the season. Hawthorn fruit may not a developmental host, but the trees conceivably could be a food source. Flies were trapped on cascara (Fig. 2) and was clearly an acceptable host, as feeding, mating, and host development (pending positive identification of pupae as western cherry fruit fly) occurred on it (Table 3), perhaps representing the first record of any cherry fruit fly using a host outside the rose family for development. Cascara is a widespread but infrequent host that occurs in shady, damp habitat, often among new growth in logged-over areas along stream banks in sage-brush, bunchgrass, and ponderosa pine systems, all areas where cherry fruit flies occur. Cascara is similar enough morphologically to cherries to have made the host transition by the fly commonplace in western Washington. Cascara fruit are green, turn red-orange, and then a dark purple, similar to the developmental sequence in cultivated sweet cherries.

Because both bitter cherries and cascara fruit are present in September, a second generation of flies can take advantage of them. The high numbers of flies in September in Skamania could be part of a second generation of flies from eggs laid a few months before. In eastern Washington about 0.3 to 1.1 per cent of the population develop into adults in August and September after the fruit had fallen, but this may be of no value to the flies because there are no available hosts in August and September or the temperatures are too high. However, in western Washington, where it is cooler, the cherry fruit flies can take advantage of cascara and bitter cherry fruit late in the season.

The relationships between cherry fruit flies and host usage are complex and may be linked to food availability and quality. An understanding of factors limiting fly host usage can benefit the cherry industry by allowing us to predict and consequently prevent further establishment of high fly

populations in areas with known or potentially new hosts. Furthermore, identification of foods and feeding behaviors on different hosts may result in better baits for direct fly control.

Table 1. Mean numbers of eggs laid per sour or sweet cherry fruit by field-collected cherry fruit flies ± SE from sour and sweet cherry trees in choice tests in the laboratory. Each replicate consisted of 3 females and 3 males and 3 fruit of each type.

Exposure		Flies from sour cherry trees			Flies from sweet cherry trees	
Time	*N*	Sour	Sweet	*N*	Sour	Sweet
2 hours	7	0.52 ± 0.26	0.37 ± 0.21	3	1.88 ± 0.62	1.54 ± 0.62
2 days	5	8.06 ± 1.87	11.67 ± 3.06	6	7.39 ± 1.04	13.05 ± 2.85
3 days	5	4.33 + 2.41	4.50 + 4.17	4	3.20 + 2.95	3.73 + 2.65

There were no significant differences within rows ($P > 0.05$).

Table 2. Developmental time (egg to pupation), pupal weight, and percent larval emergence + SE of cherry fruit flies in sour and sweet cherry fruit at 26-27 ºC.

		Host - Development Time (d)		
Fly Source	*N*	Sour (Red)	*N*	Sweet (Purple)
Sour	8	14.5 ± 0.3	7	14.3 ± 0.3
Sweet 'Bing'	6	14.2 + 0.4	9	13.7 + 0.4
		Host - Pupal Weight (mg)		
Fly Source	*N*	Sour (Red)	*N*	Sweet (Purple)
Sour	7	6.06 ± 0.38	7	5.46 ± 0.27
Sweet 'Bing'	6	5.64 + 0.31	7	5.62 + 0.23

There were no significant differences between hosts ($P > 0.05$).

Table 3. Occurrence and infestation rates of cherry fruit flies in randomly sampled native hosts and sweet and sour seedling cherries in southwestern Washington, 2002.

	Bitter Cherries				Cascara				Seedling Sweet Cherries			
Tree	Pupae	Fruit	Lv/Fruit	Tree	Pupae[a]	Fruit	Lv/Fruit	Tree	Pupae	Fruit	Lv/Fruit	
1	23	355	0.065	1	2	104	0.019	1	1	87	0.011	
2	139	2,225	0.062	2	19	190+	~0.100	2	6	125	0.048	
3	14	105	0.133	3	2	114	0.018	3	8	140	0.057	
4	25	122	0.205	4	10	114	0.088	4	6	158	0.038	
5	---	---	---	5	0	58	0	5	0	78	0	
6	---	---	---	6	---	---	---	6	5	220	0.023	
Totals	201	2,807	0.072		33	580+	~0.057		26	808	0.032	

[a]Fly identification is being confirmed by rearing to the adult stage.

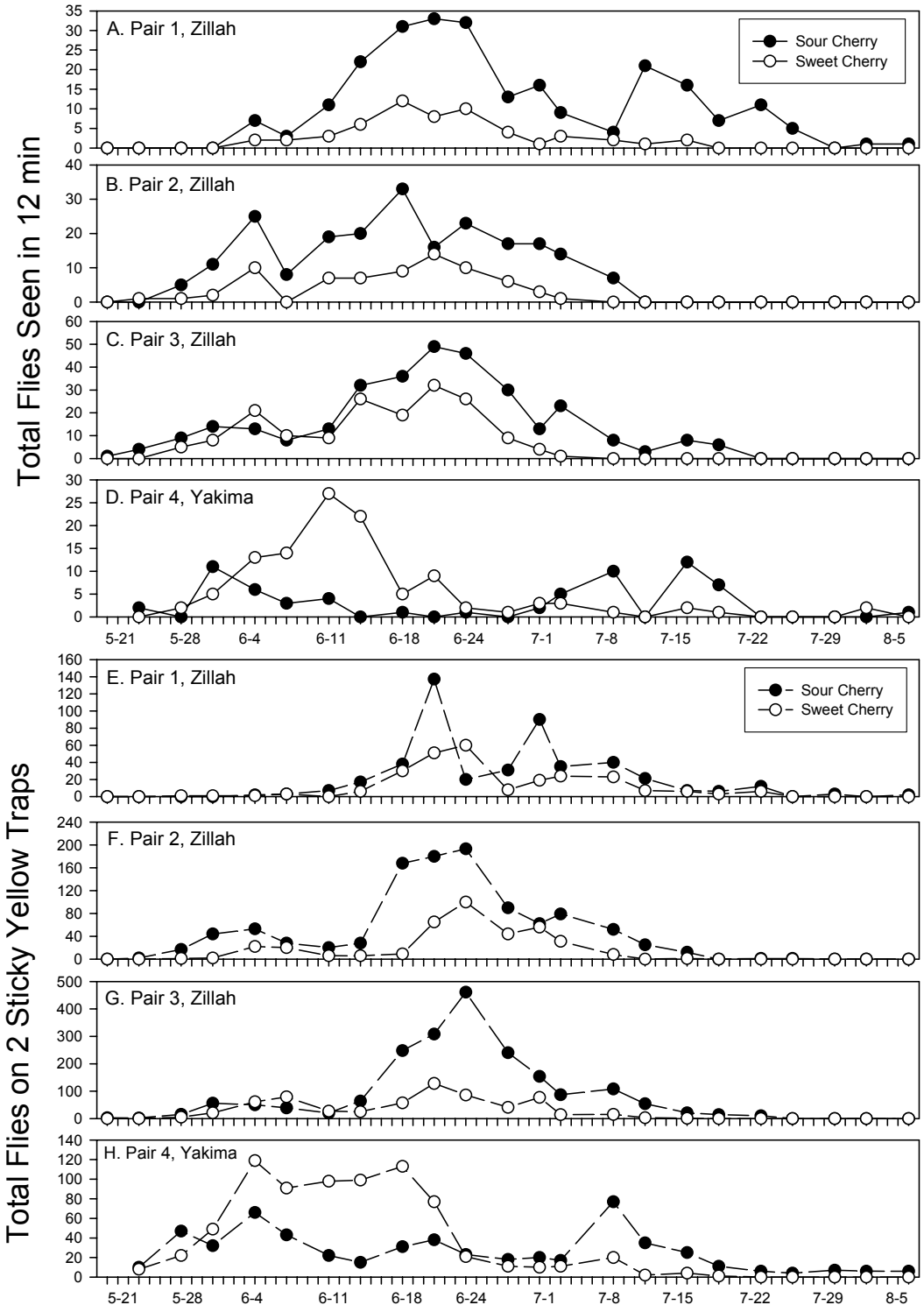


Fig. 1. Numbers of cherry fruit flies seen (A-D) and caught (E-H) on sour and sweet cherry trees in the Yakima Valley, 21 May to 5 August 2002.

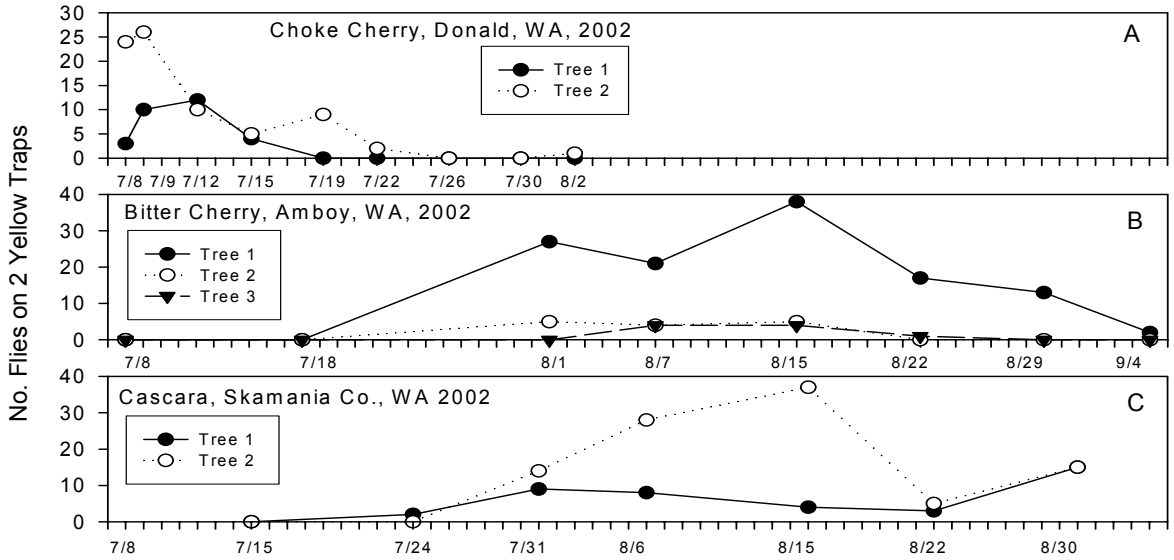


Fig. 2. Occurrence of cherry fruit flies on traps placed in (A) choke cherry, (B) bitter cherry, and (C) cascara in eastern and western Washington in 2002.

BUDGET:

Project title: Host and Feeding Preference of Cherry Fruit Fly
PI: Wee Yee
Project duration: 2001-2003
Current year: 2003
Project total (3 years): $54,478
Current year requested: $21,978

Year	Year 1 (2001)	Year 2 (2002)	Year 3 (2003)
Total	14,000	18, 500	21,977.60

Current year breakdown

Item	Year 1(2001)	Year 2 (2002)	**Year 3 (2003)**
Salaries	11,000	16,000	**18,616**[1]
Benefits (%)			**1,862**
Wages			
Benefits (%)			
Equipment	2,500	1,000	
Supplies			
Travel	750	1,500	**1,500**[2]
Miscellaneous			
Total	14,000	18,500	**21,978**

[1]GS-6 ($13.19/h), full time, 6 months, and 1 GS-3 ($9.42), full time, 3 months;
[2]To field sites.

CONTINUING PROJECT REPORT **YEAR 2/2**
WTFRC Project # CH-02-200

Project title: Cherry fruit fly distribution and trapping

PI: Wee Yee
Organization: USDA-ARS, Wapato, WA

Objectives:
2002
- Determine if cherry fruit fly distributions and infestation levels can be predicted using traps and visual counts.
- Determine relationship between infestation rates in previous years (as determined by trap catches and infestation rates) and future infestations.

2003
- Determine effects of tree size on ability of traps to detect flies and predict infestation levels.
- Determine ability of traps to reduce fly infestations.

Significant findings:
2002
- Trap catches did predict infestation levels of fruit, with red spheres and late season catches yielding better relationships and possibly predictive power.
- Trap catches detected 45% trees infested, while rearing of larvae from fruit indicated trees were 71% infested, suggesting trap sensitivity needs to be increased.
- Traps placed inside cages recaptured up to 35% of males and 46% of female, with a corresponding reduction in fruit infestation levels.
- All trees surveyed in 2000 and 2001that were positive for flies on traps were also positive in 2002, but the absolute fly numbers were not predictable.

Methods:
1. To test the effects of tree size on fly detection, either 1 or 4 red spheres baited with ammonium carbonate will be hung on the south sides of 10-20 randomly selected small-moderate size (8-15 ft) or large trees (> 15 ft) in Tri-Cities and Yakima areas (40-80 total trees). Traps will be deployed in late May and early June and left on trees for 2-2.5 weeks. In mid June, 200-500 fruit will be collected from around the trees. Fruit will be placed on screens and larvae allowed to emerge from the fruit. Larvae will be counted each day over 3 weeks. The percentages of trees that are fly positive based on trap catches, visual inspections, and larval infestations will be compared as in 2002. The hypothesis tested is that the small-moderate size trees will provide more consistent fly detections than the large trees.
2. To determine the effects of traps on larval infestations, 9 or 12 cages will be placed over individual 10-12 ft tall trees in the USDA Moxee Farm in May. Either one or 4 baited red sphere traps will be hung on each of 3 or 4 trees. A control with no traps will be included. Flies will be collected from the field, maintained in the lab, and then released inside cages in mid June. The numbers collected on traps and infestation rates in the fruit will be determined in early-mid July.

Results and Discussion:
In Union Gap and Yakima, fly catches on red spheres and yellow panels indicated that 45-48% of the 31 trees in the study were infested, whereas collection of fruit and rearing of the larvae indicated that 71% were actually infested (Table 1). These data suggest that traps can be used to detect and predict

actual infestations by the flies, but to a limited degree. Both spheres and yellow panels failed to detect moderately high infestations.

Even though traps failed to detect some infestations, red sphere and yellow panel catches were positively correlated with infestation levels in most cases, although usually not significantly (Fig. 1 and 2). Trap catches on spheres generally were better correlated with larval infestations than were yellow panels, consistent with results showing that red spheres are more attractive to flies than yellow panels (Mayer et al. 2000). However, because tree sizes and structure varied, some of the differences may have been caused by these factors and not by trap type. Tree size probably plays a key role in the detection ability of the traps. In large trees, more traps may be required, or traps must be placed at higher levels, for accurate assessment of fly populations. The location of the trees also needs to be taken into account. Almost all the trees used in this study were isolated in yard or had only a few trees nearby. Thus the trees were probably not infested by immigrating flies. However, in a few cases, the high numbers of flies and low infestation rates suggest that flies may have been dispersing through some of the yards and not staying on the trees. Tree size, fruit load, and tree location all will influence the behavior and movement of the flies and needs to be studied in relation to trap captures.

Visual inspections were usually positively correlated with trap catches. This suggests that when flies are difficult to see, the traps are also less likely to capture flies. However, in one case 81 and 69 flies were collected on one yellow trap in consecutive weeks but only 2 and 3 flies were seen. Periodic visual examinations on trees thus seem less reliable than trap catches in determining infestations.

Up to the present, the standard method for detecting flies is the use of yellow sticky traps placed in representative unmanaged trees (AliNiazee 1978). Because catches on red spheres may be better indicators of actual fly presence and infestations, red spheres perhaps should be used instead of yellow panels in select locations where fly populations are low. AliNiazee (1978) presented data showing a positive relationship between fly captures on Pherocon ICPY traps baited with Mago-Vial and Pherocon AM Standard traps and mean % infestation at harvest, but when infestations were higher in abandoned, untreated trees, there was not a strong correlation between the two.

Nine trees spread over Kennewick, Richland, Prosser, Yakima, and Cle Elum that were positive for flies on traps in 2000 and 2001 were positive again in 2002, indicating that infestations persist in trees year after year. Whenever fruit are available, flies will tend to stay on the same trees and will not disperse far from it, as dispersal tendencies by the fly are relatively low (Frick et al. 1954, Jones and Wallace 1955). Surprisingly, the actual numbers caught on traps were not predictable from year to year, except between 2000 and 2002 ($r = 0.624$, $P = 0.073$; 2000 and 2001 and 2001 and 2002, $P > 0.07$), suggesting either traps are not sensitive enough or that fly populations naturally fluctuate greatly from year to year, depending on fruit load and other factors. Increased trap sensitivity is important because reliable predictions of infestation levels can lead to better planning for control measures in the following years.

Traps placed inside caged trees recaptured up to 30% of released flies (Table 2). The actual infestations were not significantly reduced, but trapped trees did tend to have lower infestation rates (Table 2). Further tests are required to determine if more than 4 traps per tree and stronger baits are needed to draw flies into the traps. Because the supercharger lures used in the study may have lost all their ammonia after 1 week, a longer-lasting ammonia source may be needed to continually trap flies throughout the season and reduce infestations.

The overall results of this study indicate that traps, deployment of traps, and the attractants used with traps need to be improved to increase their ability to predict fly infestations. In the infested back yard tree, this ability could determine whether it is necessary to exert control measures or not. By removing flies in trees with low, difficult to detect infestations, the threat of flies immigrating into commercial orchards can be substantially reduced. Additionally, the removal of flies by traps can reduce populations to a level that may allow more effective control using non-insecticide methods. Both of these outcomes will benefit the cherry industry.

Table 1. Relationship between numbers of trees infested with *Rhagoletis indifferens* and fly-positive trees based on numbers caught on traps and seen on cherry trees in the Yakima Valley, May-June 2002. E, early, 22 May-4 June; L, late, 4-13 June.

			% Trees Positive for Flies Based On:			
		% Trees	Trap Catch		Visual Counts	
Treatment	*N*	Infested[c]	E	L	E	L
1 Red sphere[a]	9[b]	56	33	33	33	33
4 Red spheres[a]	9	67	44	44	22	44
1 Yellow Panel	8	75	50	62	25	38
4 Yellow Panels	5	100	60	60	20	20
Totals – all treatments	31	71%	45%	48%	25%	35%

[a]Spheres not baited with ammonium carbonate early sampling, but was for late sampling.
[b]One tree that was trapped only during the late period not included; [c]Based on larvae in fruit.

Table 2. Percentages of *Rhagoletis indifferens* ± SE recaptured by red sphere traps and infestation rates inside field cages in Moxee, WA, 19 June to 15 July, 2002. Cumulative total flies released inside parentheses. Three cages per treatment. M = males, F = females.

	No. Flies Released			Cumulative Percent Recaptured			
Release	Per Cage		Control	1 Red Sphere		4 Red Spheres	
No.[a]	F	M		M	F	M	F
1	13	90	------	16.3 ± 6.4a	28.2 ± 9.3a	28.2 ± 3.1a	46.2 ± 27.7a
2	9 (22)	44 (134)	------	14.0 ± 4.0a	30.3 ± 7.6a	22.0 ± 1.0a	32.7 ± 21.5a
3	7 (29)	19 (153)	------	14.4 ± 4.5 a	33.3 ± 8.1a	22.1 ± 0.9a	35.1 ± 15.8a
				Infestation of Fruit			
Total No. Larvae/Tree			355.0 ± 93.5a	240.0 ± 87.7a		103.0 ± 35.8a	
No. Larvae/Fruit			0.322 ± 0.086a	0.251 ± 0.092a		0.102 ± 0.36a	

[a]18 June, 25 June, 5 July Means followed by the same letter within rows are not significantly different (ANOVA, $P > 0.05$).

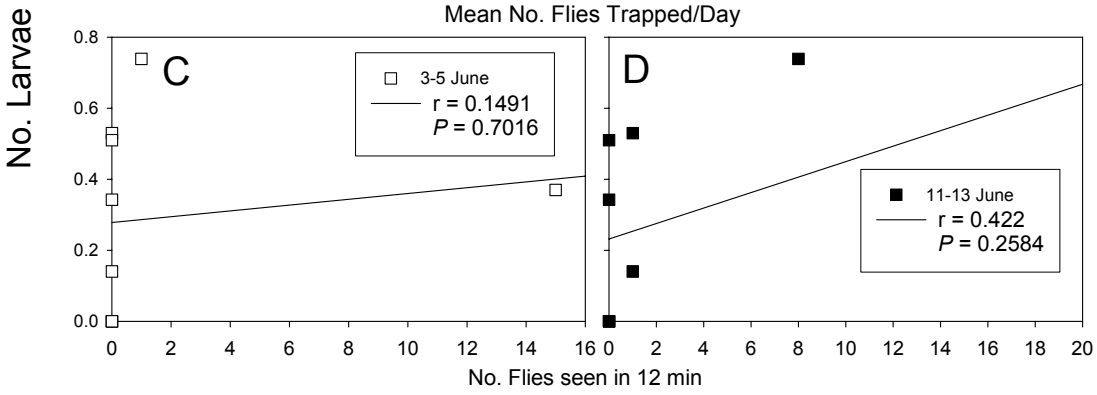


Fig. 1. Relationships between red sphere trap catches, numbers seen, and numbers of larvae inside cherry fruit in Union Gap and Yakima, WA, 2002.

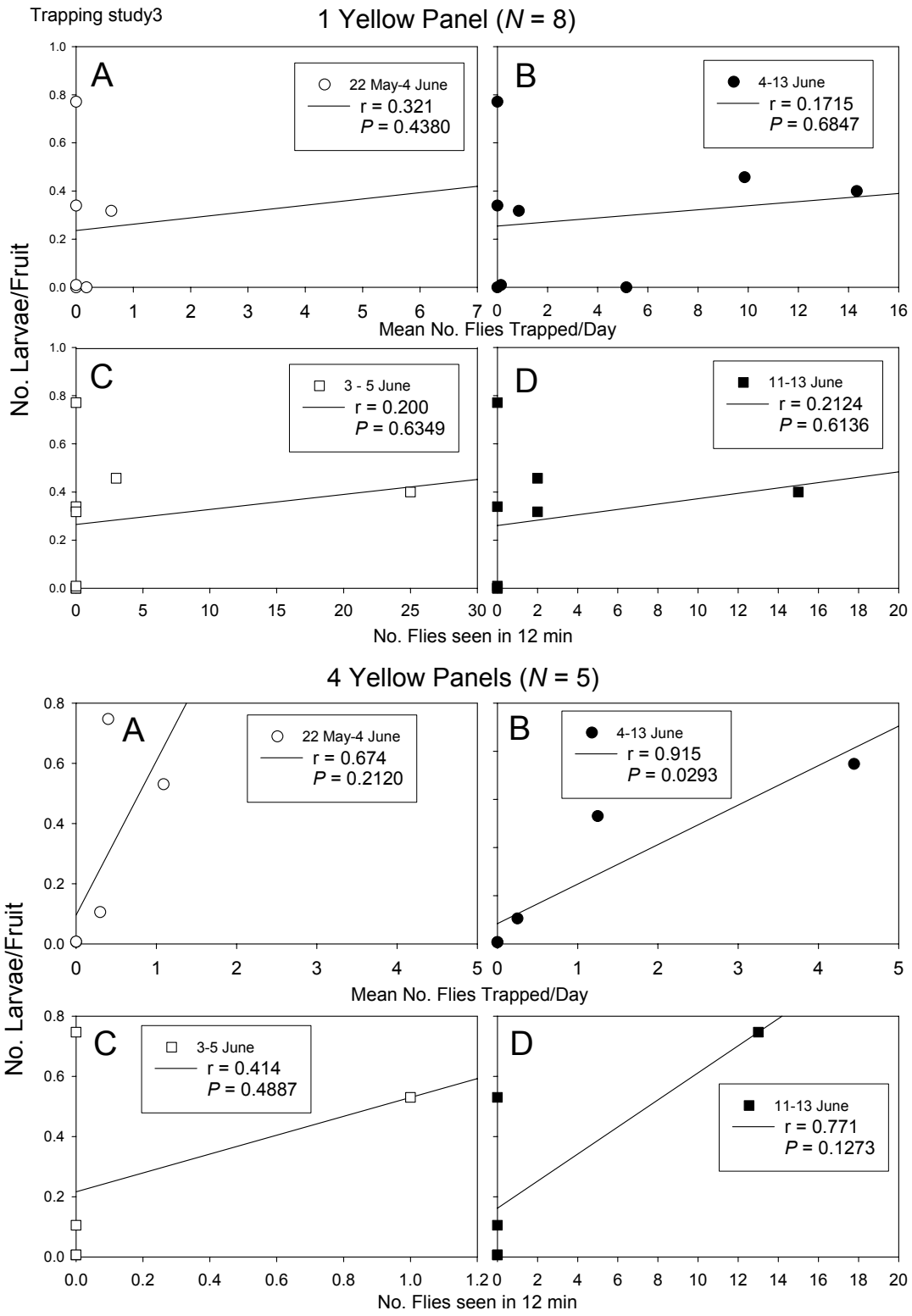


Fig. 2. Relationships between yellow panel trap catches, numbers seen, and numbers of larvae inside cherry fruit in Union Gap and Yakima, WA, 2002.

BUDGET:

Project title: Cherry fruit fly distribution and trapping
PI: Wee Yee
Project duration: 2001-2003
Current year: 2003
Project total (3 years): $22,660
Current year requested: $12,660

Year	Year 1 (2002)	**Year 2 (2003)**
Total	10,000	**12,660.72**

Current year breakdown

Item	Year 1(2001)	**Year 2 (2003)**
Salaries	9,000	**11,055**[1]
Benefits (%)		
Wages		**1,105**
Benefits (%)		
Equipment		
Supplies	1,000	**500**[2]
Travel		
Miscellaneous		
Total	10,000	**12,660**

[1]GS-5 ($11.84/h) and GS-3 ($9.42/h), full time, 3 months;
[2]Traps

References

AliNiazee, M. T. 1978. The western cherry fruit fly, *Rhagoletis indifferens* (Diptera: Tephritidae) 3. Developing a management program by utilizing attractant traps as monitoring devices. Can. Entomol. 110: 1133-1139.

Frick, K. E., H. G. Simkover, and H. S. Telford. 1954. Bionomics of the cherry fruit flies in eastern Washington. Wash. Agr. Expt. Stations Tech. Bulletin. 13:1-66.

Jones, S. C. and L. Wallace. 1955. Cherry fruit fly dispersion studies. J. Econ. Entomol. 48: 616-617.

Mayer, D. F., L. E. Long, T. J. Smith, J. Olsen, H. Riedl, R. R. Heath, T. C. Leskey, and R. J. Prokopy. 2000. Attraction of adult *Rhagoletis indifferens* (Diptera: Tephritidae) to unbaited and odor-baited red spheres and yellow rectangles. J. Econ. Entomol. 93: 347-351.

CONTINUING PROJECT REPORT **YEAR 3/3**
WTFRC Project # CH-01-12

Project title: Factors Affecting Mating By Cherry Fruit Flies

PI: Wee Yee
Organization: USDA-ARS, Wapato, WA

Objectives:
2001
- Document and describe mating behaviors of the western cherry fruit fly in the laboratory.
- Determine effects of age on mating success and fecundity.
- Document mating behaviors of flies in the field.

2002
- Demonstrate the presence of a mating pheromone in the fly using laboratory wind tunnel and field bioassays.
- Compare the ability of laboratory- and field-collected males to attract females.
- Characterize the chemicals responsible for attraction of females to males.

2003
- Continue to establish presence of pheromones or odors involved in mating behavior.
- Determine visual factors involved in successful mating by flies.
- Determine effect of nutrition on mating success.
- Effects of age on mating and egg hatch success in the laboratory and field.

Significant findings:
2001
- Flies displayed no courtship behavior; rather, mating was initiated when males jumped on females.
- Flies that were young mated less frequently than older flies; females exposed to males laid an average of 250 eggs.
- Mating was initiated while males were on fruit; mating occurred frequently whenever temperatures were > 80 ºF.

2002
- Extensive laboratory and field bioassays using male flies as a source of odor suggested the females do not respond to chemicals released by males (but further work is needed).
- Neither laboratory nor field-collected males (which may be exposed to different nutrients in the field) attracted females in the absence of visual cues in the laboratory or field.
- Flies mated infrequently during the first 14-19 d after emergence in the field.
- The numbers of eggs in unmated flies were lower than in mated flies, suggesting older flies with higher egg loads are more likely to mate.

Methods:
1. Further laboratory studies to determine the presence or absence of a mating pheromone will be conducted. Larger tunnel designs and changes in temperatures, light intensity, and wind speed inside tunnels will be tested to improve conditions that promote greater or more natural behavior.
2. To provide evidence for visual attraction by females to males, tests will be conducted with 20 virgin female flies and 20 males inside 10 × 4 ft plastic cages. Sixty cherries will be hung from the ceiling of the cages. Fruit will be unbaited, baited with dead flies (pinned or glued to fruit), or with live males (that will naturally cling to the fruit). Two-minute observations will be made every hour over 8 hours to determine whether females preferential visit fruit

with live males. In other fruit flies, pheromones seem to operate over short distances only (< 1 ft). If so, the cage size will enable the detection responses of females to male odors. A second test will be conducted with artificial red and orange fruit to determine the interaction between color and male presence on mating.

3. Male and female flies will be fed diets of sucrose only, sucrose-yeast, and cherry juice only. They will be paired in all combinations and exposed to wax domes for egg laying and observed for mating. Eggs will be collected, placed on moist filter papers, and hatch rate determined. Egg hatch will be used as an indication of successful insemination.
4. Final work will be conducted on age-related mating effects in the laboratory and field by pairing males and females of known ages in the lab and by pairing flies collected over the season in the field inside cages. Insemination will be determined as in 3.

Results and Discussion:

Laboratory bioassays using various wind tunnels based on those used successfully with the European cherry fruit fly were conducted in the laboratory. Tunnels consisted of plexiglass cages and a series of funnels made with plastic containers. Virgin females were placed in a holding cage at one end of the tunnel. From 20-50 laboratory-reared males were placed inside a cage at the opposite end with food and water. A control cage with food and water was placed next to it, allowing the females to go either into it or the trap cage with males. A small axial fan was placed behind the cage holding females to draw odor through the tunnel. In theory, odors from the male cage were drawn through the tunnel and would have been detected by the females. If females were stimulated, they would have flown upwind. However, in most tests, female responses were too low to detect differences between the control and male treatment. When the sliding door on the cage holding females was opened, the females did not fly upwind, but rather stayed on the sides of the cages and walked very slowly for hours. The response of female western cherry fruit flies thus were different than that of the European species, which responded to male odors inside tunnels within 1 hour (Katsoyannos 1976, 1982, Katsoyannos et al. 1980).

A field experiment was conducted in an infested backyard cherry tree in June 2002 in which 30 males were held inside paper cups with food and water. A sticky board was placed over the cages to trap any flies that flew to the cups. Despite a one-week exposure, no flies were trapped on the boards. A second experiment in which 20 males were placed inside red spheres was conducted. Comparisons were made with red spheres baited with ammonia, a known food attractant, and a control. Observations of flies alighting on the traps were made for 30 min and showed that flies, including other males, were attracted to the ammonia-baited sphere within 10 min of trap deployment. Although females did alight on spheres baited with males, the numbers were not significantly different from the controls.

The above results suggest female flies are not responsive to odors of males or that the males need to be in a specific physiological or behavioral state to release a pheromone. Because males were kept inside cages or spheres for bioassays and were not hanging on fruit waiting for females (the natural behavior), they may not have been in the right state to release any sex attractants. The background environment may need to be very specific for this to occur. Clearly further work is needed to provide evidence that a pheromone exists, as it does in other fruit flies. If a pheromone is absent, mating may depend mostly if not solely on vision. The question is how flies find one another using vision only; perhaps repeated flights to fruit by females needing to lay eggs are sufficient to achieve successful mating.

An earlier study had shown that responses of females to males were based largely on age in the laboratory (Table 1). Males and females that were 3-9 d mated less frequently than older flies, especially those that were 30-43 d old. Other age treatments were intermediate. Despite the differences in percentages of young and old flies that mated, the numbers of matings per day and the mean duration of mating were not age-related.

To further determine whether mating was affected by age and whether there is evidence that mating is pheromone-based or simply visual, mating by flies was determined by observing trees and by pairing males and females that were caught in the field inside cages in Zillah and Roslyn (Fig. 1), WA. In Zillah, mating propensity as determined by observations in trees and inside cups was < 20% for the first 14 days after first fly detection, when fruit were small, hard, and green. At Roslyn, mating tendencies were <25% for the first 19 days after flies were seen. These results suggest that during the early part of the season, flies do not mate frequently and thus have a lower chance of bearing fertile eggs than later in the season.

When placed inside cages in the field, mating usually occurred within 10 min. No wing fanning or movement of the abdomen by the male, which would suggest the release of a pheromone, was seen. Females also were not agitated or "excited", which would have indicated they were stimulated by an odor. However, males clearly responded to the sight of females. Upon seeing a female, a male made jumps to mount her. A pair often struggled momentarily on the bottom of the cage before coupling was complete. In many cases the females resisted the attempts made by the male. However, once coupled, mating was prolonged.

In Zillah, females that mated had higher numbers of eggs than females that did not throughout most of the season, but especially during the early part. By the end of the season mated and unmated females had about equal numbers of eggs (Fig. 2). A similar overall pattern was seen in Roslyn (Fig. 2). The differences in mating frequency and egg loads between flies in Zillah and Roslyn were not related to higher fly densities in Zillah because mating in Roslyn was low both in trees and inside cups, suggesting there was a physiological difference between the flies. Flies in Zillah had higher egg loads throughout the season perhaps because these flies had better nutrition, which in turn resulted in greater mating tendencies. If so, nutrition may affect mating success by increasing egg production, which causes females to seek fruit with males.

The results indicate that mating in cherry fruit flies is governed mostly by vision and the flight of females to fruit, where males congregate and where egg laying occurs. There, the males jump on females, and mating takes place on or off the fruit. It is likely females do not seek the males, but that males detect the females by vision alone, although this needs to be definitively shown. Further research into factors that disrupt the ability of males to mate with females (and vice versa) will aid in managing the fly. If the chemical, visual, or environmental factors linked to mating success can be identified, new management strategies for the flies may be possible. This will benefit the cherry industry by helping reduce the numbers of pesticide applications needed because of the decreased threat of flies entering commercial orchards.

Table 1. Frequency of mating and mean numbers of matings/day and mean mating duration (minutes) of single male-female pairs of flies different ages in the laboratory.

Age (days)		No.	No. Pairs	% Pairs	No. Matings	Mating
Male	Female	Pairs	Mated	Mating	per day + SE	Duration + SE
3-9	3-9	32	5	15.6	0.08 ±0.03a	40.12 ± 17.50a
3-9	17-29	25	8	32.0	0.27 ± 0.09a	60.95 ± 13.68a
17-29	3-9	15	4	26.7	0.20 ±0.12a	73.05 ± 7.48a
17-29	17-29	47	11	23.4	0.44 ± 0.22 a	36.76 ± 9.43a
30-43	30-43	16	8	50.0	0.33 ±0.14 a	26.85 ± 11.44a

Means followed by same letters within columns are not significantly different ($P < 0.05$).

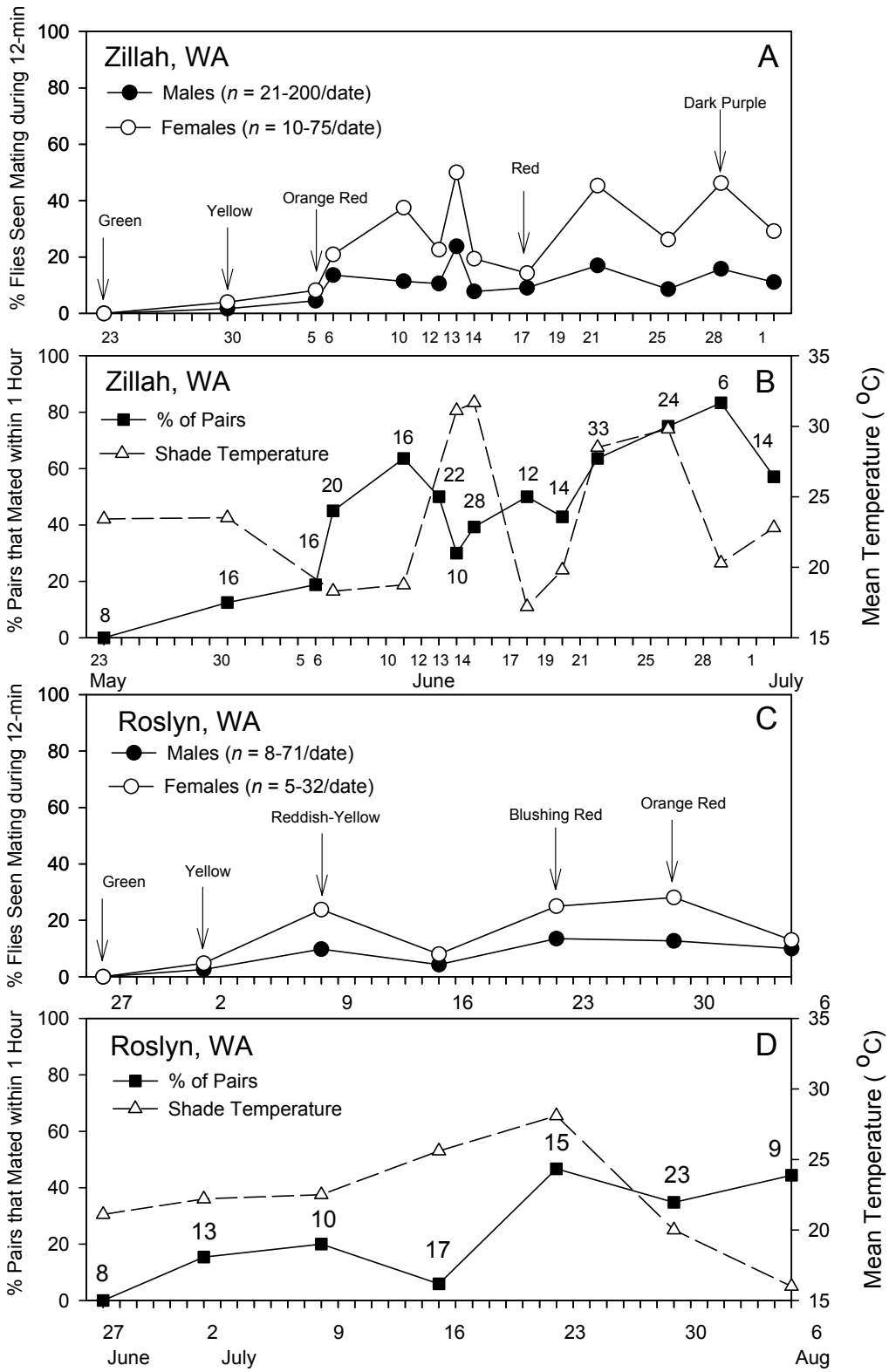


Fig. 1. Percentage of cherry fruit flies seen mating in trees and % that mated inside cups over the season in Zillah and Roslyn, WA, 2002.

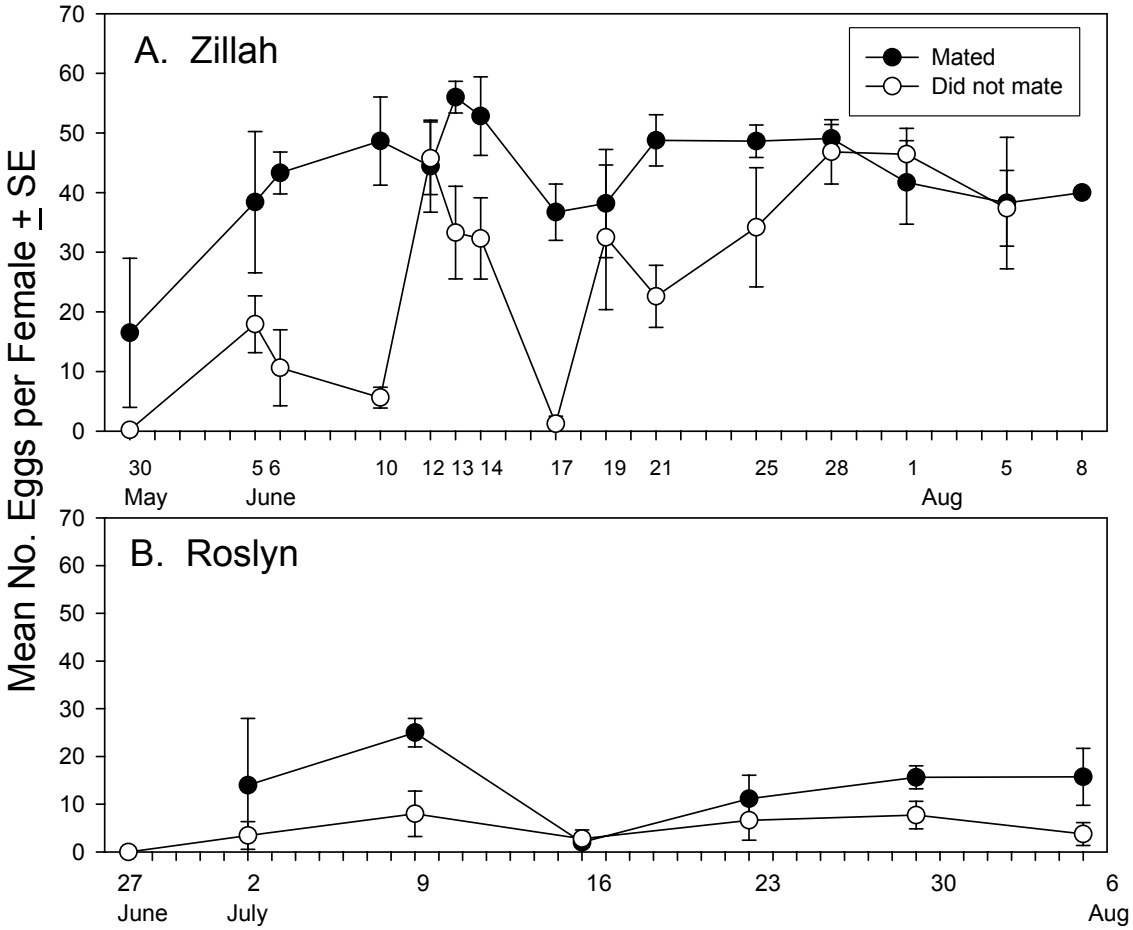


Fig. 2. Numbers of eggs inside females that mated and did not mate inside cups in the field in Zillah and Roslyn, WA, 2002.

BUDGET:

Project title: Factors Affecting Mating By Cherry Fruit Flies
PI: Wee Yee
Project duration: 2001-2003
Current year: 2003
Project total (3 years): $51,746
Current year requested: $10,746

Year	Year 1 (2001)	Year 2 (2002)	Year 3 (2003)
Total	22,000	19,000	10,745.88

Current year breakdown

Item	Year 1(2001)	Year 2 (2002)	**Year 3 (2003)**
Salaries	15,000	17,500	**7,951**[1]
Benefits (%)			**795**
Wages			
Benefits (%)			
Equipment	6,000	1,500	**1,500**[2]
Supplies			
Travel	1,000		**500**[3]
Miscellaneous			
Total	22,000	19,000	**10,746**

[1]One GS-3 or GS-4 ($9.42 or $10.58/h), full time, 3 months and 1 GS-3, 50% time, 3 months.
[2]Cages, cherries, chemicals for leaf concentrate analysis; [3]To field sites.

References

Katsoyannos, B. I. 1976. Female attraction to males in *Rhagoletis cerasi*. Environ. Entomol. 5: 474-476.

Katsoyannos, B. I., E. F. Boller, and U. Remund. 1980. A simple olfactometer for the investigation of sex pheromones and other olfactory attractants in fruit flies and moths. Z. Ang. Entomol. 90: 105-112.

Katsoyannos, B. I. 1982. Male sex pheromone of *Rhagoletis cerasi* L. (Diptera, Tephritidae): factors affecting release and response and its role in the mating behavior. Z. Ang. Entomol. 2: 187-198.

CONTINUING PROJECT REPORT **YEAR 3/3**
WTFRC Project # CH-01-10

Project title: Use of Nematodes to Manage Cherry Fruit Fly

PI: Wee Yee
Organization: USDA-ARS, Wapato, WA
Co-PI and affiliation: Lerry Lacey, USDA-ARS

Objectives:
2001
- Conduct efficacy studies of *Bacillus thuringiensis* (BT) beta-exotoxin against pre-pupal western cherry fruit fly larvae under laboratory and simulated field conditions.
- Evaluate the potential of steinernematid nematodes for control of pupae and emerging adults of flies under laboratory and field simulated conditions.

2002-2003: Further evaluate the efficacy of nematodes in the field. Specifically to:
- Determine effects of *Steinernema carpocapsae* and *S. feltiae* on mortality of larval flies in the field.
- Effects of these nematodes on adult mortality in the field.

Significant findings:
2001
- Beta-exotoxin caused 100% mortality of adult but not of larval cherry fruit flies in the laboratory.
- Steinernematid nematodes caused 62-100% mortality of larvae and 15-53% mortality of emerging adults of flies under laboratory and field simulated conditions.

2002
- *Steinernema carpocapsae* and *S. feltiae* caused significantly higher mortality than controls in the laboratory and inside pails with soil placed in the field.
- Nematodes retained their ability to infect fly larvae after 6 days in the laboratory under simulated field conditions.

Methods:
1. Field experiments at the USDA-ARS Moxee Farm cherry orchard (which is fly infested) will be conducted in 2003. Wooden boxes that are 2 by 2 ft and 6 inches deep will be placed into the ground beneath individual cherry trees and filled with soil from fly-free (non-cherry) orchards at the farm. Bottoms of boxes will be perforated to allow the passage of water. This will be conducted in the fall of 2002 to allow soil enough time to compact naturally and take on characteristics of the surrounding soil. In early to mid June, all fruit from trees will be removed to prevent natural infestations. The soil will be raked to loosen it and then wetted thoroughly for 1 h prior to nematode applications. Ten to 30 minutes after nematode applications, 100 fly larvae will be added. One week after applications, the boxes will be removed and the soil will be examined for the presence of dead and live pupae. Soil moisture and temperatures will be continuously recorded. Treatments will be *S. carpocapsae* and *S. feltiae* and a control. There will be 10 replicates (trees) of each treatment used, for a total of 30.
2. In another experiment, the same treatments will be applied twice during the season on soil beneath trees with natural infestations following similar methods as the above. In the spring of 2004, emergence cages will be placed on the ground to collect emerging adults. There will also be 10 trees for each treatment, for a total of 30.

Results and Discussion:

Results. Pupae were not infected by nematodes (Table 1), but all three nematode species tested infected adult flies (Table 2). *Steinernema carpocapsae* was the most effective, causing 11-53% mortality of emerged adults, whereas *S. feltiae* and *S. intermedium* caused 3-5% and 0-7% mortality, respectively. Reproduction of *S. carpocapsae* occurred inside one fly. Both sexes of flies were infected.

Steinernema feltiae and *S. carpocapsae* at low and high concentrations caused 62-100% mortality of fly larvae. *Steinernema intermedium* was the least effective of the three nematodes, but also caused high mortality (Table 3). *Steinernema carpocapsae* was generally more effective than *S. feltiae.* In tests 1, 2, and 3, about 40% 75%, and 0%, respectively, of the larvae exposed to nematodes died before pupating, indicating that death occurred in < 24 h.

When nematode efficacy over days was compared, *S. carpocapsae* and *S. feltiae* were nearly equal on all 6 days (Table 4). Results of tests 1, 2, and 3 differed somewhat, but the higher nematode concentration combined with 20% moisture seemed more effective than other treatments. In all 3 tests, *S. carpocapsae* caused greater mortality than *S. feltiae* (Table 4).

In a test that compared the effects of laboratory and orchard silt loam soils on nematode behavior and fly mortality, *S. carpocapsae* was observed to spend more time on the surfaces of both soil types than *S. feltiae*. Despite these behavioral differences, the two species caused equally high mortality of larvae in both soil types (Table 5).

Mortalities caused by nematodes in test 1 and test 2 in the field were significantly higher than in the controls (Table 6), and comparable to those seen in some laboratory tests. Control mortality was relatively high, but control larval and pupal recovery rates in tests 1 and 2 were 69% and 63%, respectively, compared nematode-treatment rates that were 47 and 45%. Unlike the laboratory experiments, *S. carpocapsae* overall was slightly less effective than *S. feltiae*.

Discussion. The results definitively show that while pupae are not susceptible to nematodes, adults are, and that larvae are by far the most susceptible stage. The low infection rates of adults, especially by *S. feltiae* and *S. intermedium*, suggest that the period when flies were still soft (about 6 h) was insufficient for immediate nematode infection or that the periods of the adult exposure to the nematodes was too short. When exposed for long periods, adults of other fruit flies can become heavily infected (Beaver and Calkins 1984, Lindegren and Vail 1986, Ghally 1988).

Unlike the adults, fly larvae were easily infected by nematodes, consistent with earlier work (Patterson Stark and Lacey 1999). Although fly larvae burrowed quickly into the soil, this did not prevent high mortality caused by all three nematode species, as the nematodes were negatively phototactic and sought the larvae beneath the surface. This was true at nematode concentrations of 5×10^5 and 10^6 IJ/m^2. Doubling the nematode concentration did not double the mortality rate, but did significantly increase fly mortality. Like with the adults, *S. carpocapsae* was generally more effective than *S. feltiae* against the larvae.

Both *S. carpocapsae* and *S. feltiae* were effective in killing larval flies over a 6-d period, with *S. carpocapsae* being more effective. The ability of *S. carpocapsae* to infect fly larvae over time in soil greatly enhances its potential value as a control agent. The lower mortality caused by the nematodes at 45% soil moisture was probably caused by reduced motility due to excessive water. The precise role of soil moisture on effectiveness of nematodes needs to be determined. Although the effectiveness was negatively impacted by high moisture, the superiority of *S. carpocapsae* over *S. feltiae* was consistent with the other laboratory tests.

The experiment that compared soil types suggests that *S. carpocapsae* does not readily move vertically in either compact silt loam orchard or loose laboratory soil, whereas *S. feltiae* does. Despite these behavioral differences, the denser orchard silt loam soil surprisingly did not negatively affect the ability of *S. carpocapsae* and *S. feltiae* to find and kill the larvae. This suggests that steinernematid nematodes can be effective in loose and compact soil in the field.

The field experiment indicated that both nematodes are effective under the fluctuating temperatures of the field. *Steinernema carpocapsae* was slightly less effective than *S. feltiae* under

field natural conditions, suggesting changes in temperatures affect *S. carpocapsae* more than they do *S. feltiae*. Further field studies are needed to determine the role changes in environmental factors have on the effectiveness of the two nematodes.

The overall results indicate that *S. carpocapsae* and *S. feltiae* hold promise as effective biological control agents of larval cherry fruit flies. Although use of nematodes would not be feasible in commercial orchards, at present most cherry fruit fly problems originate in abandoned lots or in unmanaged yards of homeowners. In such situations, the use of steinernematid nematodes from commercial sources (which are found in Iowa, California, and other states) may be a feasible management option to insecticide use, especially when combined with fruit sanitation measures.

The ability of nematodes to survive and persist in field soils and under the warm and fluctuating temperatures during June and July will be critical to their effectiveness. Under such conditions, the survival of nematodes can be enhanced greatly if applications are made on wet soil during the more humid and cooler hours of the day, especially if fly larvae drop from trees during these times. Although adult flies emerge in the cool morning hours, it is not known when larvae emerge and drop from fruit. Larvae of the related walnut husk fly drop from nuts during the cooler portions of the day, between 0530-0800 hours, when temperatures are 4-22 ºC and humidity is 95-40%. This may occur in the cherry fruit fly as well. Understanding nematode moisture and temperature requirements and fly larval ecology will aid in the development of a program in which environmental factors and timing of applications can be manipulated for effective fly control.

Table 1. Percent mortality ± SE of *Rhagoletis indifferens* exposed as pupae to $10^6/m^2$ of infective juveniles (IJ) of *Steinernema carpocapsae* and *S. feltiae* in soil with 20% moisture in the laboratory. Each replicate consisted of 10 pupae.

		Pupae 1-3 cm below soil surface		Pupae on soil surface	
Treatment	*N*	Test 1	Test 2	Test 3	Test 4
Control	5	5.0 ± 5.0a	0.0 ± 0.0a	0.0 ± 0.0a	2.0 ± 2.0a
S. carpocapsae	5	21.1 ± 11.6a	2.0 ± 2.0a	4.0 ± 2.4a	4.0 ± 2.4a
S. feltiae	5	15.2 ± 6.6a	2.0 ± 2.0a	6.0 ± 4.0a	0.0 ± 0.0a

Means followed by the same letter within columns are not significantly different (ANOVA, followed by Duncan's multiple range test, $P > 0.05$).

Table 2. Percent infection of emerged adult cherry fruit flies ± SE exposed to 10^6 infective juveniles/m^2 of three *Steinernema* species in soil in the laboratory. Each treatment consisted of 5 replicates of 100 pupae each.

	Percent of Emerged Adult Flies Infected		
Control	0 ± 0a	0 ± 0a	0 ± 0a
S. carpocapsae	11.3 ± 5.8b	53.1 ± 12.5b	21.7 ± 3.7b
S. feltiae	3.2 ± 2.0ab	4.1 ± 1.7a	6.1 ± 1.2c
S. intermedium	0 ± 0a	6.7 ± 2.9a	0.7 ± 0.7a

Means followed by the same letter within columns are not significantly different (ANOVA, followed by Duncan's multiple range test, $P > 0.05$).

Table 3. Percent mortality ± SE of cherry fruit flies exposed as 3rd instar larvae to two concentrations of infective juveniles (IJ) of three *Steinernema* species 10-30 min after nematode applications in soil with 20% moisture in the laboratory. Each treatment consisted of 5 replicates of 10 larvae each.

	Overall Percent Mortality of Larvae and Pupae		
Treatment	Test 1	Test 2	Test 3
Control	6.0 ± 4.0a	22.0 ± 9.7a	4.0 ± 2.4c
S. carpocapsae – L	100 ± 0b	100 ± 0b	62.0 ± 6.6b
S. carpocapsae – H	100 ± 0b	100 ± 0b	84.0 ± 6.8a
S. feltiae – L	100 ± 0b	100 ± 0b	54.0 ± 12.1b
S. feltiae – H	100 ± 0b	100 ± 0b	78.0 ± 4.9ab
S. intermedium - L	66.0 ± 11.7c	96.0 ± 4.0b	--------
S. intermedium – H	54.0 ± 12.1c	92.0 ± 8.0b	--------

L, Low = 5×10^5 IJ/m^2; H, High = 10^6 IJ/m^2
Means followed by the same letter within columns are not significantly different (ANOVA, followed by Duncan's multiple range test, $P > 0.05$).

Table 4. Percent mortality ± SE of cherry fruit flies exposed as 3rd instar larvae to 5×10^5 or 1×10^6 infective juveniles/m^2 of *Steinernema carpocapsae* and *S. feltiae* placed onto soil with 20% or 45% moisture at various times after nematode applications at 25-27 ºC in the laboratory. Each replicate consisted of 10 larvae.

Time After Application	*N*	Control	*S. carpocapsae*	*S. feltiae*
		Test 1- $5 \times 10^5/m^2$ IJ, 20% Soil Moisture		
0 d (10-30 min)	8	4.3 ± 2.0a (a)	78.6 ± 5.5a (b)	87.5 ± 3.4a (b)
2 d	4	7.5 ± 4.8a (a)	92.5 ± 2.5 a (b)	52.5 ± 6.3b (c)
4 d	4	10.0 ± 0.0a (a)	95.0 ± 5.0a (b)	92.5 ± 2.5a (b)
6 d	4	25.0 ± 9.6a (a)	77.5 ± 16.5a (b)	70.0 ± 4.1b (b)
		Test 2- $10^6/m^2$ IJ, 20% Soil Moisture		
0 d (10-30 min)	5	8.0 ± 5.8a (a)	90.0 ± 5.5a (b)	90.0 ± 5.5a (b)
2 d	5	10.0 ± 4.5a (a)	92.0 ± 3.7 a (b)	50.0 ± 7.7b (c)
4 d	5	24.0 ± 12.9a (a)	100.0 ± 0.0a (b)	42.0 ± 8.0b (a)
6 d	5	2.0 ± 2.0a (a)	84.0 ± 8.1a (b)	40.0 ± 14.8b (c)
		Test 3- $5 \times 10^5/m^2$ IJ, 45% Soil Moisture		
0 d (10-30 min)	5	10.0 ± 7.7a (a)	32.0 ± 4.9a (b)	24.0 ± 6.8a (b)
2 d	5	18.0 ± 8.6 a (a)	52.0 ± 8.0 b (b)	30.0 ± 7.1ab (ab)
4 d	5	4.0 ± 2.4a (a)	48.0 ± 5.8ab (b)	38.0 ± 5.8ab (b)
6 d	5	8.0 ± 2.0a (a)	60.0 ± 5.5b (b)	44.0 ± 5.1b (b)

Means followed by the same letter within rows (day effect) and columns (in parentheses, species effect) are not significantly different (ANOVA, followed by Duncan's multiple range test, $P > 0.05$).

Table 5. Mortality of cherry fruit flies ± SE exposed as 3rd instar larvae to 10^6 infective juveniles/m^2 at 25-27 ºC in laboratory and orchard silt loam soils in the laboratory. Each replicate consisted of 10 larvae.

		Percent Mortality		
Treatment	*N*	Laboratory Soil	*N*	Orchard Silt Loam Soil
Control	5	4.0 ± 2.0a	5	20.0 ± 7.0a
S. carpocapsae	5	80.0 ± 3.0b	5	78.0 ± 10.0b
S. feltiae	5	66.0 ± 10.0b	5	74.0 ± 7.0b

Means followed by the same letter within columns are not significantly different (ANOVA, followed by Duncan's multiple range test, $P > 0.05$).

Table 6. Percent mortality ± SE of *Rhagoletis indifferens* exposed as 3rd instar larvae to two concentrations of infective juveniles (IJ) of *Steinernema carpocapsae* and *S. feltiae* in loam silt soil in pails placed into the ground in a cherry orchard. Each replicate consisted of 50 larvae.

		Test 1: 18, 21 June			Test 2: June 24	
Treatment	*N*	% of Total[a]	% of Recovered	*N*	% of Total[a]	% of Recovered
Control	4	36.0 ± 3.7a	7.3 ± 1.8a	3	48.0 ± 1.2a	16.8 ± 3.4a
S. carpocapsae – L	4	79.0 ± 2.1bc	53.5 ± 3.5b	3	59.3 ± 4.7ab	33.9 ± 2.5ab
S. carpocapsae – H	4	67.5 ± 5.7b	40.7 ± 4.7 b	3	76.0 ± 7.0bc	56.8 ± 11.2b
S. feltiae – L	4	76.5 ± 6.6bc	57.4 ± 10.7b	3	80.0 ± 7.2c	46.0 ± 8.8b
S. feltiae – H	4	85.5 ± 7.5c	62.4 ± 11.5b	3	80.0 ± 3.5c	52.8 ± 7.7b

[a]Larvae and pupae not recovered were assumed to have died and disintegrated in the soil.
L, Low = 5×10^5 IJ/m^2; H, High = 10^6 IJ/m^2
Means followed by the same letter within columns are not significantly different (Duncan's multiple range test, $P > 0.05$).

BUDGET:

Project title: Use of Nematodes to Manage Cherry Fruit Fly
PI: Wee Yee
Project duration: 2001-2003
Current year: 2003
Project total (3 years): $27,275
Current year requested: $12,275

Year	Year 1 (2001)	Year 2 (2002)	**Year 3 (2003)**
Total	7,500	7,500	**12,275**

Current year breakdown

Item	Year 1(2001)	Year 2 (2002)	**Year 3 (2003)**
Salaries	7,000	7,000	**9,796**
Benefits (%)			**979**
Wages			
Benefits (%)			
Equipment	500	500	**500**
Supplies			
Travel			**1,000[2]**
Miscellaneous			
Total	7,500	7,500	**12,275**

[1]2 GS-3 ($9.42/h), full time, 3 months; [2]Sites to collect flies.

References

Beavers, J. B. and C. O. Calkins. 1984. Susceptibility of *Anastrepha suspensa* (Diptera: Tephritidae) to steinernematid and heterorhabditid nematodes in laboratory studies. Environ. Entomol. 13: 137-139.

Ghally, S. E. 1988. Pathogenecity of the nematodes *Steinernema feltiae* Filipjev in relation to different insect hosts. J. Egyptian Society of Parasitology. 18 (1): 297-304.

Lindegren, J. E. and P. V. Vail. 1986. Susceptibility of Mediterranean fruit fly, melon fly, and oriental fruit fly (Diptera: Tephritidae) to the entomogenous nematode *Steinernema feltiae* in laboratory tests. Environ. Entomol. 15: 465-468.

Patterson Stark, J. E. and L. A. Lacey. 1999. Susceptibility of western cherry fruit fly (Diptera: Tephritidae) to five species of entomopathogenic nematodes in laboratory studies. J. Invert. Pathology. 74: 206-208.

FINAL REPORT
WTFRC Project # CH-01-08

Project Title: Mechanical Harvester for Fresh Market Quality Stemless Sweet Cherries

PI: Donald L. Peterson, Agricultural Engineer USDA/ARS
Appalachian Fruit Research Station
Kearneysville, WV

Cooperators: Matthew Whiting, Bob Harris, Dennis Hayden

Objectives: The principal objective of this research was to develop a mechanical harvesting system for stemless, fresh market quality sweet cherries. Secondary objectives were to: (1) determine compatible tree training and cultural practices, (2) develop an effective fruit removal actuator and positioning system, (3) develop fruit catching/collecting components that minimize damage, and (4) test the system under field conditions to determine feasibility.

Significant findings:

- A two-piece experimental harvester was developed. Both units contained a rapid displacement actuator (RDA) to effect fruit removal, an effective system to position the RDA against main scaffolds, soft catching/collecting conveyors, an automated bin filler, and an easily positioned and effective trunk seal that consisted of spring-loaded padded catcher-pans.
- In 2002 ethrel was effective in reducing fruit detachment force from over 500 gm to the 200-300 gm range; fruit removal averaged better than 90%.
- Harvested rates of over 100 tree/hour were obtained with over 2000#/hour of cherries harvested. With properly trained limbs, harvest rate should easily exceed 150 trees/hour.
- The harvester caught 90% of the cherries removed. The spring-loaded padded catcher-pans were very effective in sealing the tree trunk except when limbs were too low or trellis members too wide near the ground. Most fruit lost to the ground was either in front of or behind the catching surfaces. Longer catching surfaces would significantly reduce fruit loss.
- Again in 2003 machine harvested fruit quality compared favorably with hand harvesting. Machine harvested sweet cherries had only 3 % more damage than hand harvested cherries and averaged 61% fresh market quality.

Methods: In 2003 we hope to test the experimental harvester at two locations (Roosevelt, Processor) to continue evaluation of tree training compatibility, ethrel response, fruit quality, harvest rates and capacity, and therefore better represent commercial potential. Methods for improved bin handling will be explored and incorporated into harvester design.

Results and discussion: A complete mechanical harvester has been developed for stemless sweet cherries. In three years of testing, machine harvested cherries had only 1 to 4% more damage than commercial hand harvesting and essentially no significant differences in the amount of fresh market quality fruit. Machine components are reliable. Tree training requirements have been identified that will result in the highest removal, best quality, and most efficient operation of the harvester. Each tree should have 2 to 3 main scaffolds per side with each scaffold angled 45° to 60° to the horizontal. Lateral fruiting branches should be stiff and 2 to 3 feet in length. With the proper training system, this mechanical harvesting concept should be commercially feasible, and lower grower costs and dependence on hand labor.

Budget: 2000-2002

Title: Mechanical Harvester for Fresh Market Quality Stemless Sweet Cherries

PI: **Donald L. Peterson**
Project duration: **3 years**
Project total (3 Years) **$85,500**

Year	Year 1 (2000)	Year 2 (2001)	Year 3 (2002)
Supplies	6,500	28,000	4,800
Travel	7,000	7,000	6,200*
Transportation	7,000	10,000	9,000**
Total	20,500	45,000	20,000

* Per diem for 2 people for 21 days, car rental, and airfare for 2 people for harvester evaluation.

** Transportation of harvesters from West Virginia to Washington and return. Transportation within Washington.

FINAL REPORT
WTFRC Project # CH-01-06

Title: Cherry Phytochemicals

Principal Investigator: Ronald E. Wrolstad
Department of Food Science & Technology (FST), OSU
Phone: (541) 737-3591; E-mail: ron.wrolstad@orst.edu

Cooperators: Arusa Chaovanalikit, Ph.D. student, FST
Robert W. Durst, Sr. Research Assistant, FST

Collaborators: Roberto Nuñez-Elisea, Mid-Columbia Research & Extension Center
Anita Azarenko, Department of Horticulture, OSU
Carl Payne, Oregon Cherry Growers
Balz Frei, Linus Pauling Institute, OSU

Objectives:

- Identify and determine the concentrations of anthocyanin pigments and polyphenolics in selected cherry cultivars.

- Do comparative measurements of anthocyanin and polyphenolics in peel, flesh, and pits, and monitor their changes when processed into frozen, canned, and brined fruit.

- Determine the *in vitro* antioxidant activities of cherry extracts by the Oxygen Radical Absorbing Capacity (ORAC) and Ferric Reducing Antioxidant Potential (FRAP) assays.

- Identify cherry polyphenolics and determine qualitative and quantitative differences with respect to cultivar, distribution between peel, flesh and pit, and effects of processing.

Significant findings:

•The proportion by weight of peel, flesh and pits for Bing, Royal Anne, Rainier and Montmorency cherries has been determined for the 2001 season. Peel (17%), flesh (65%), pit (7%), loss (11%).

•Total anthocyanin pigments, total phenolics, and antioxidant activities have been determined for extracts of peel, flesh and pits for the four cultivars. Anthocyanin pigments, total phenolics and antioxidant activities are highest in the skin. Bing is highest in anthocyanin.

•Montmorency is highest in total phenolics, with Royal Anne being slightly higher than Bing in total phenolics. Rainier is lowest. Total phenolics has a high correlation with antioxidant activities as measured by ORAC and FRAP.

•Bing cherries frozen and stored at –23°C showed substantial anthocyanin pigment degradation (66% loss after three months and 88% after six months) in contrast to cherries stored at –70°C (10 and 12% loss, respectively).

•Approximately 50% of the Bing cherry anthocyanins and total phenolics are distributed into the syrup with canning.

•Sulfite brining of Bing and Royal Anne cherries showed that most of the phenolics were redistributed into the brine solution.

• Presence of the following cherry polyphenolics have been confirmed: chlorogenic acid, neochlorogenic acid, *p*-coumaroyl-quinic acid, gallic acid (tentative), epicatechin, catechin, quercetin-3-glucoside, qucercetin-3-rutinoside, procyanidin-B1 (tentative).

• The HPLC profiles for Bing, Rainier and Royal Anne are similar. Qualitative patterns for flesh and skin are similar with higher proportions of flavan-3-ols occurring in the flesh. The pits are higher in phenolic acids and lower in flavanols. Montmorency cherries contain additional polyphenolics with procyanidins being present in the flesh.

Methods:

Fruit Source

Cherry samples were collected from the Mid-Columbia Research and Extension Center (Roberto Nuñez-Elisea) and the Lewis Brown Farm (Anita Azarenko). Fruit for freezing, canning and brining processing studies were provided by Oregon Cherry Growers (Carl Payne).

Processing Trials

Bing cherries were canned and frozen in the OSU FST pilot plant using unit operations typical of commercial processes. Both Royal Anne and Bing cherries were used for brining experiments. Changes in both canned and frozen fruit were monitored during storage over five and six months, respectively.

Sample Extracts

Materials were cryogenically milled with liquid nitrogen, extracted with acetone and partitioned with chloroform to produce an aqueous extract as previously described (2001-2002 proposal). Extracts of peels, flesh and pits for Bing, Royal Anne, Rainier and Montmorency cherries were stored at –70°C.

Separation, Identification and Quantification of Individual Polyphenolics

Analytical and semi-preparative HPLC were used for separating and identifying anthocyanins and polyphenolics. Solid-phase extraction using C-18 resin was used for isolating anthocyanin and polyphenolic fractions (Skrede et al., 2000). Anthocyanin pigments were identified by HPLC retention behavior, uv-visible spectral characteristics and electro-spray mass spectra (ESMS).

Identification and measurement of the concentrations of the other polyphenolics— flavonols, flavan-3-ols, procyanidins, and cinnamic acid derivatives are in progress. Acid hydrolysis and saponification reactions are being used in conjunction with HPLC for partial characterization.
Electro-Spray Mass Spectroscopy (ESMS) will also be used in conjunction with HPLC and UV-visible spectroscopy for polyphenolic identifications. ESMS analyses are being conducted at the OSU Department of Chemistry on a fee basis. Quantities of individual compounds will be measured by compound class (anthocyanins, flavonols, flavan-3-ols, procyanidins, cinnamates, etc.) with HPLC via the external standard method. Our laboratory is well experienced in these methodologies (Spanos et al., 1990; Karadeniz et al., 2000).

Measurement of Total Anthocyanins, Total Phenolics and Anti-oxidant Activity.

Total anthocyanins were determined by the pH differential method (Wrolstad et al., 1982) and total phenolics by the Folin-Ciocalteau procedure (Singleton and Rossi, 1965).The antioxidant activity of cherry extracts were determined by Oxygen Radical Absorbing Capacity (ORAC) and Ferric Reducing Antioxidant Potential (FRAP) assays and reported as Trolox equivalents. Analyses were determined at the Linus Pauling Institute (Deborah Hobbs) on a fee basis ($110/sample).

Results and Discussion:

Distribution of Cherry Components by Weight

The proportion of cherry components in fruit samples for the 2001 season is shown in Table 1 below. A 10-11.4% loss occurred in peeling, pitting and weighing the samples. The proportions are similar for the different cultivars. The pits that account for 7% of the fruit on a fresh weight basis are a potential source for polyphenolics from processing wastes.

Distribution of Anthocyanin Pigments

The anthocyanin content of skin, flesh and pit for the four cultivars are also shown in Table 1. Bing is richest in anthocyanin pigment and is the only cultivar that has pigmentation in the flesh. Montmorency contains substantial pigment in the peel, while Rainier and Royal Anne have light pigmentation. Pit pigmentation is likely from flesh material adhering to the pit.

Distribution of Total Phenolics

Table 1 also shows the distribution of total phenolics skin, flesh and pit for the four cultivars. Anthocyanins will contribute to total phenolics, but other polyphenolics (flavonols, flavan-3-ols, procyanidins and cinnamates) will also be measured. The peel is richest in phenolics. Montmorency is highest in total phenolics for all components. Royal Anne cherries, while having very little anthocyanins, are slightly higher in total phenolics than Bing's. Rainier is substantially lower in total phenolics than the other varieties.

Antioxidant Activities of Cherry Components

Antioxidant activity as measured by Oxygen Radical Absorbing Capacity (ORAC) and Ferric Reducing Antioxidant Potential (FRAP) for skin flesh and pit of the four cultivars is also shown in Table 1. Montmorency is highest in antioxidant activity. Anthocyanin pigments are very effective in trapping free radicals and are believed to account for the high antioxidant activity of Bing skins. Royal Anne cherries are low in anthocyanin pigment and contain none in the flesh. The edible portion, however, is actually higher than Bing's in antioxidant activity. Other polyphenolics must account for the high antioxidant activity of Royal Anne cherries. Total phenolics had high positive correlation (R - 0.90) with ORAC values.

Table 1: Anthocyanins, total phenolics, ORAC, and FRAP of flesh, pit, skin, and edible portion of four cherry cultivars

Cultivars	Portion	% Distribution	Anthocyanins (mg/100g fw)	Total Phenolic (mg/gfw)	ORAC (μmoles/g fw)	FRAP (μmoles/g fw)
Bing	Flesh	65.5 ± 3.2	26.0 ± 0.7	1.34 ± 0.18	9.07 ± 0.35	7.28 ± 0.24
	Pit	5.7 ± 0.4	10.4 ± 3.1	0.92 ± 0.09	5.94 ± 0.91	5.04 ± 0.96
	Skin	17.5 ± 0.5	60.6 ± 2.5	3.33 ± 0.41	28.26 ± 1.10	21.05 ± 0.55
	Loss	11.3 ± 2.8				
	Edible portion		29.67 ± 2.34	1.85 ± 0.13	14.94 ± 0.90	15.90 ± 1.42
Royal Anne	Flesh	62.2 ± 0.7	0.1 ± 0.10	1.76 ± 0.03	13.10 ± 0.44	9.03 ± 0.19
	Pit	7.9 ± 0.1	0.2 ± 0.05	1.04 ± 0.08	5.68 ± 0.53	4.98 ± 0.36
	Skin	18.1 ± 0.2	2.2 ± 1.1	3.51 ± 0.13	27.44 ± 1.66	17.08 ± 1.11
	Loss	11.8 ± 0.6				
	Edible portion		0.45 ± 0.22	2.29 ± 0.10	14.49 ± 2.20	15.53 ± 0.48
Rainier	Flesh	71.4 ± 0.8	0.0 ± 0.0	0.65 ± 0.05	4.62 ± 0.18	2.27 ± 0.22
	Pit	5.5 ± 0.3	0.1 ± 0.0	0.54 ± 0.04	3.38 ± 0.26	2.00 ± 0.13
	Skin	13.5 ± 0.8	2.1 ± 0.4	1.42 ± 0.05	10.50 ± 1.51	5.92 ± 0.39
	Loss	9.6 ± 0.7				
	Edible portion		0.51 ± 0.04	0.75 ± 0.02	4.98 ± 0.51	2.92 ± 0.26
Montmorency	Flesh	60.4 ± 1.9	0.0 ± 0.09	3.01 ± 0.29	15.00 ± 1.00	13.81 ± 0.26
	Pit	7.2 ± 0.1	0.8 ± 0.08	1.57 ± 0.02	9.78 ± 0.28	8.48 ± 0.85
	Skin	17.7 ± 0.2	36.5 ± 1.6	5.58 ± 0.33	51.02 ± 1.97	47.96 ± 1.33
	Loss	14.7 ± 1.7				
	Edible portion		8.72 ± 0.80	4.07 ± 0.18	25.57 ± 3.99	37.56 ± 0.95

Values are mean ± standard deviations, n=3 for % distribution while n=4 for anthocyanins, total phenolics, %polymeric, ORAC, and FRAP.

Effect of Frozen Storage on Bing Anthocyanins and Antioxidant Activity

Bing cherries were pitted, frozen and stored at -23 and -70°C. The results are shown in Table 2. There was substantial loss of anthocyanin pigments during storage at -23°C, 66% after 3 months and 87% after 6 months. Storage at -70°C was effective in preventing degradation with a 10% loss after 3 months and 12% at six months. Native enzymes, particularly polyphenoloxidase, are believed to responsible for this degradation. Total phenolics did not show such a marked decrease. This can be explained by the fact that degraded and polymeric pigments will respond to the Folin-Ciocalteau reagent in the total phenolics determination. Cherries stored at -70°C had even higher antioxidant

activities than fresh fruit. One possible explanation for this unexpected finding is that the polyphenolics may have been more efficiently extracted from fruit stored at -70°C.

Table 2: Effect of freezing, storage temperature, and time on total anthocyanins, total phenolics, and ORAC of pitted Bing cherries.

Storage temperature	Total Anthocyanins, mg/100g			Total Phenolics, mg/g			ORAC, Trolox equiv/g		
	Storage time (month)			Storage time (month)			Storage time (month)		
	Fresh	3	6	Fresh	3	6	Fresh	3	6
-23° C	63.7	21.5	8.0	1.9	1.5	1.0	13.1	12.6	9.41
-70° C		57.4	56.4		2.1	2.0		24.6	23.8

Effect of Canning on Bing Cherry Anthocyanins, Total Phenolics, and Antioxidant Activities

Bing cherries were canned and the distribution of anthocyanins and total phenolics in fruit and syrup measured after processing and after 5 months storage. Results are shown in Table 3. The anthocyanins and phenolics are distributed almost equally between fruit and syrup. While anthocyanins leach from the fruit into the syrup during canning, there is effectively no total loss of anthocyanin pigments during canning. The pronounced color change in fruit that occurs with canning must be due to pigment transfer, formation of enzymatic and non-enzymatic browning pigments, as well as physical changes. A substantial loss of total anthocyanins occurred when canned fruit was stored at 22°C (42%) whereas an 11% loss occurred at 2°C storage. An apparent increase in total phenolics may be due to increased extraction efficiency, and/or generation of lower molecular weight phenolics or other reactive compounds. There is an apparent increase in antioxidant activity with canning and with storage time. This may be due to increased extraction efficiency of polyphenolics or generation of compounds with antioxidant activity, e.g. melanoidins from nonenzymatic browning reactions.

Table 3: Effect of canning, storage temperature, and storage time on total anthocyanins, total phenolics, and ORAC of pitted Bing cherries in light syrup.

Samples	Storage temperature (°C)	Total Anthocyanins, mg/100g		Total Phenolics, mg/g		ORAC, Trolox equiv/g	
		Storage time (month)		Storage time (month)		Storage time (month)	
		0	5	0	5	0	5
Fresh		63.7	-	1.9	-	13.1	-
Canned cherries	2	35.1	28.0	1.2	1.3	8.9	14.2
	22	33.3	19.7	1.1	1.2	9.0	12.8
Canned syrup	2	29.9	29	1.4	1.1	8.5	15.4
	22	35.6	20.3	1.2	1.1	9.5	16.2

Effect of Brining on Bing and Royal Anne Anthocyanins, Total Phenolics, and Antioxidant Activities

Both Bing and Royal Anne cherries were preserved in bisulfite brine following operations similar to commercial practice. Total anthocyanins, total phenolics, and antioxidant activities were determined for fruit before brining, and in fruit and brine after six months. Results are shown in Table 4. Most of the anthocyanins and total phenolics are redistributed into the brine. Thus spent brine is a potential source for these compounds that could possibly be used in natural colorant, nutraceutical, and natural antioxidant applications.

Table 4: Effect of brining on total anthocyanins, total phenolics, and ORAC in Bing and Royal Anne cherries.

Sample	Total Anthocyanin, mg/100g	Total Phenolics, mg/g	ORAC, Trolox equiv/g
Fresh Bing Fruit	26.1	1.8	13.0
Brined Bing Fruit	0.5	0.2	0.7
Bing Brine	11.1	1.5	10.0
Fresh Royal Anne Fruit	0.5	2.3	14.5
Brined Royal Anne Fruit	0.09	0.20	0.5
Royal Anne Brine	0.12	2.56	13.6

Qualitative Composition of Cherry Polyphenolics and their Changes with Processing

Anthocyanins

The anthocyanin composition of sweet and sour cherries are well established. We confirmed that cyanidin-3-glucoside, cyanidin-3-rutinoside, peonidin-3-glucoside and peonidin-3-rutinoside are the principal anthocyanins of sweet cherries. Montmorency differs by containing in addition cyanidin-3-(2^G-glucosylrutinoside) and cyanidin-3-sophoroside. Determinations of the qualitative changes that occur with processing are in progress.

Polyphenolics

Identification of the following polyphenolics has been confirmed by HPLC retention behavior and their u.v. spectral characteristics. Further identification by mass-spectroscopy is in progress.

Cinnamic acid derivatives: Chlorogenic acid, neochlorogenic acid, *p*-coumaroylquinic acid
Phenolic acids: Gallic acid (tentative)
Flavan-3-ols; Catechin, epicatechin
Procyanidins: Procyandin-B1
Flavonols: Qucercetin-3-glucoside, quercetin-3-rutinoside, plus additional quercetin-glycosides, kaempferol-glycosides (tentative)

Distribution of Cherry Polyphenolics

Figure 1 shows the HPLC polyphenolic chromatograms for extracts of Bing skin, flesh and pits. The qualitative composition of skin and flesh are similar with higher proportions of flavan-3-ols occurring in the flesh. The pits contain higher proportions of phenolic acids and lower proportions of flavanols. Chlorogenic acid and its isomers comprise the major polyphenolics. These compounds are excellent substrate for native polyphenoloxidase. Royal Anne and Ranier chromatograms are similar to Bing. HPLC polyphenolic chromatograms for extracts of Montmorency skin, flesh and pits are shown in Figure 2. Montmorency contains additional polyphenolic peaks. Procyanidins are present in the flesh. Quantitation of these individual polyphenolics and their changes with processing are in progress.

Presentations at Professional Meetings and Publication Plans

The following poster presentation was made at the Annual meeting of the Institute of Food Technologists in Anaheim where Arusa Chaovanalikit earned 2nd place in IFT's Fruit and Vegetable Products Division's Graduate Student Poster Competition.

A. Chaovanalikit and R. E. Wrolstad. Anthocyanin Pigment and Total Phenolics Content of Fresh and Processed Cherries and their Antioxidant Properties. Poster 76C-3, IFT Annual Meeting, Anaheim, CA, 6/15-19/02.

The following manuscript is in draft form and will be submitted to J. Food Sci. An additional manuscript on the polyphenolic composition of cherries and their changes with processing is in preparation.

A. Chaovanalikit and R. E. Wrolstad. Anthocyanin pigment and total phenolic content of fresh and processed cherries and their antioxidant properties.

This research is the subject of the Ph.D. thesis of Arusa Chaovanalikit whose defense is planned for spring, 2003.

Figure 1: HPLC polyphenolic chromatograms for extracts of Bing pit, flesh and skin.

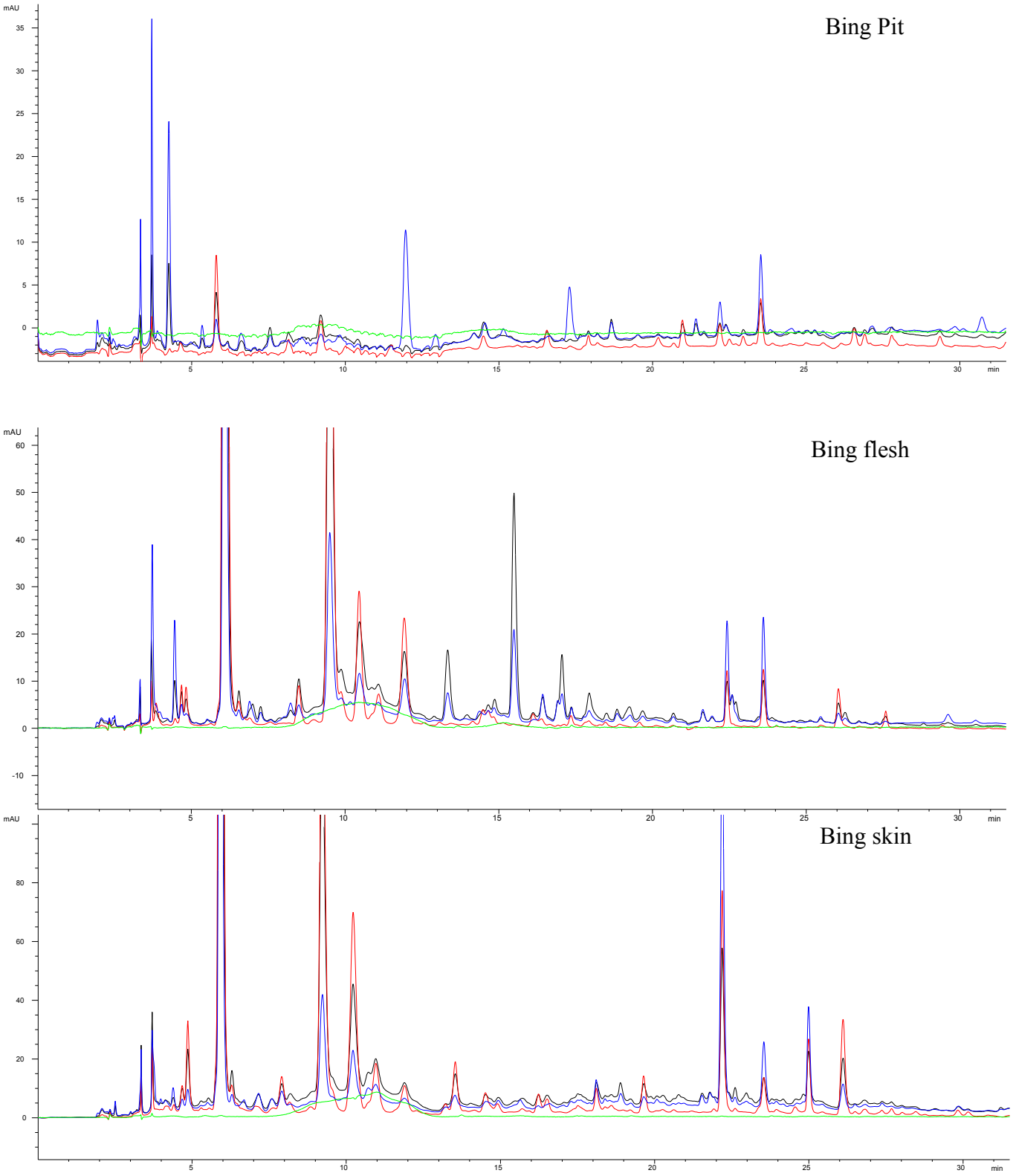
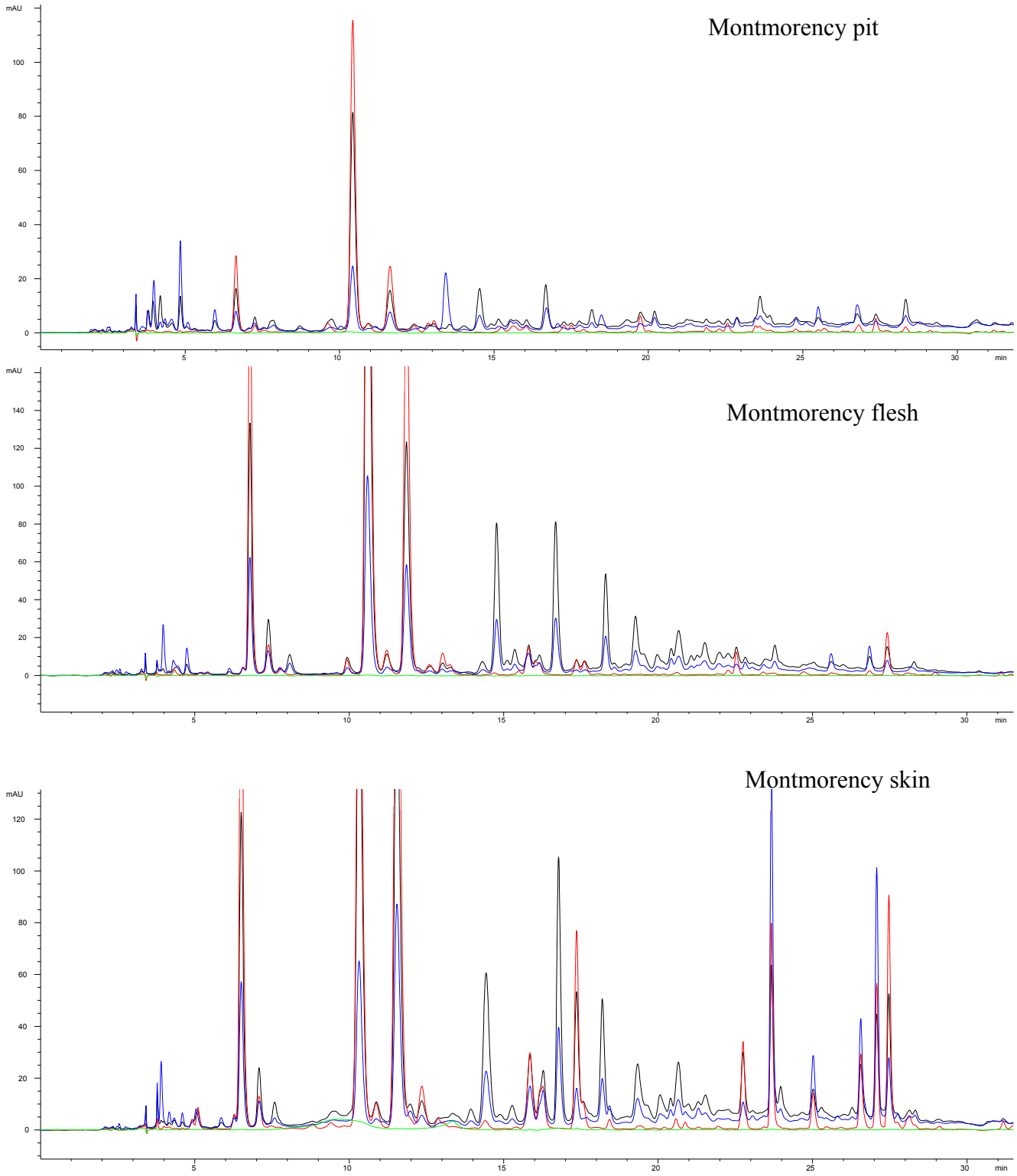


Figure 1: HPLC polyphenolic chromatograms for extracts of Montmorency pit, flesh and skin.



References

Giusti, M. M. and Wrolstad, R. E. 2001. Unit F1.2.1-13. Anthocyanins. Characterization and Measurement with UV-Visible Spectroscopy. In, *Current Protocols in Food Analytical Chemistry* . R. E. Wrolstad (Ed). John Wiley & Sons, NY.

Hong, V. and Wrolstad, R. E. 1990. Use of HPLC separation/photodiode array detection for characterization of anthocyanins. J. Agric. Food Chem. 38: 708-715.

Karadeniz, F., R. W. Durst and R. E. Wrolstad. 2000. Polyphenolic composition of raisins. J. Agric. Food Chem. 48: 5343-5350.

Singleton, V. L. and J. L. Rossi. 1965. Colorimetry of total phenolics with phsphomolybdic phosphotungstic acid reagents. Am. J. Enol. Vitic. 16: 144-158.

Skrede, G., R. E. Wrolstad and R. W. Durst. 2000. Changes in anthocyanins and polyphenolics during juice processing of highbush blueberries (*Vaccinium corymbosum* L.) J. Food Sci. 65: 357-364.

Spanos, G.A. and R.E. Wrolstad. 1990. The influence of processing and storage on the phenolic composition of Thompson Seedless grape juice. J. Agric. Food Chem. 38: 1565 1571.

Budget:

Title: Cherry Phytochemicals
PI: Ronald E. Wrolstad
Project duration: 1999-2003
Current Year: 2003 (Funded project is scheduled for completion 3/31/03)
Total project cost (4 years) $57,000
Original Budget Request: (8/1/02-1/31/03)

Year	Year 1 (1999)	Year 2 (2000)	Year 3 (2001)	Year 4 (2002)
Total	3,000	20,000	20,000	14,000

Note: Year 1 was a preliminary study on cherry polyphenolics and antioxidant activity. Funds were expended for undergraduate student wages, antioxidant measurements and laboratory supplies.

Current year breakdown:

Year	Year 2 (2000)	Year 3 (2001)	Year 4 (2002)
Salaries	15,411	15,853	8,943[a]
Benefits	459	488	429[b]
Supplies	4,130	3,659	2,628[c]
Travel			1,000[d]
Publication costs			1,000[e]
Total	20,000	20,000	14,000

[a]Chaovanalikit, GRA, Ph.D, 0.49 FTE for six months, $8,532; Durst, Sr. Research Assistant, 0.02 FTE for six months, $411.
[b]Chaovanalikit, GRA OPE (3%); Durst, OPE (42%).
[c]HPLC supplies, extraction solvents; ORAC and FRAP analyses at Linus Pauling Institute at $110/sample; ESMS analyses at OSU Chemistry Dept at $150/hr.
[d]Reporting research results at professional meeting (IFT, Anaheim, CA).
[e]Page charges and reprints for articles in peer-reviewed journals (J. Food Sci.)

CONTINUING PROJECT REPORT
WTFRC Project #: CH-01-02

Title:	Identification of sweet cherry dwarfing rootstock candidates from MSU's tart cherry germplasm collection.
PI:	Amy Iezzoni
Organization:	Department of Horticulture, Michigan State University (MSU)
Cooperators:	Matt Whiting (WSU-Prosser), Bill Howell (NRSP5, Prosser) & Ron Perry (MSU)

Objectives: Identify rootstock selections from MSU's vast cherry germplasm collection that may have commercial potential as dwarfing precocious rootstocks for sweet cherry. MSU selections included as rootstock candidates in field trials at MSU and WSU will have been demonstrated to propagate well and to be virus tolerant.

Significant findings in YR 2002:

- Twelve out of the 50 MSU rootstock selections that were screened for virus tolerance in 2002 were found to be sensitive to Prune Dwarf Virus (PDV) and *Prunus* Necrotic Ringspot Virus (PNRSV). These susceptible selections were discontinued.
- 25 additional MSU rootstock selections were planted in the test plot at MSU's Clarksville Horticultural Experiment Station (CHES) with Hedelfingen scion. This represents an additional 119 trees.
- 19 MSU rootstock selections were planted in the first planting of the test plot at WSU-Prosser. This represents 102 trees.
- It is projected from nursery counts that YR 2003 and 2004 plantings will result in the evaluation of 93 MSU rootstock selections totaling 667 and 519 trees, respectively, at CHES and Prosser.
- All but one of the 20 MSU rootstock selections planted at CHES in 2001 induced flowering on Hedefingen and Bing scions. In general, the MSU rootstock selections induced similar or fewer flowers per tree than the GI 6 rootstock.

Methods:

This project consists of four stages:

1. Propagation: Years 1997 –2001 (completed)
2. Virus testing: Years 1998 – 2002 (completed)
3. Planting of grafted trees in test plots: Years 2001 – 2004
4. Rootstock plot evaluation at MSU & WSU: beginning in YR 2001-MSU & YR 2002-WSU.

Years 2002 to 2004, for which a 3 year budget was developed, represent Transition Years in which virus testing, budding and plot establishment will be sequentially completed. Year 2005 will be the first year where the only activity will be plot evaluation.

The data to be collected on the trees in the MSU and WSU test plots will be tree survival, trunk cross-sectional area, bloom date, flower number and/or bloom density, crop load and fruit size. Crop load and in special cases actual yield and fruit size data, will only be collected from the most promising selections. This is because it is not necessary to record detailed data from selections that are not performing well and will obviously be discarded.

Results and Discussion:

Twenty-four percent (12/50) of the MSU selections that were screened for PDV and PNRSV sensitivity by Bill Howell were found to be susceptible. These 12 selections were discarded. The

decision to include the virus screen prior to plot testing has proven to be a valuable strategy due to the large number of selections discarded.

There are currently 45 MSU rootstock selections, totaling 273 trees, under test in the plot at CHES (Fig. 1 & 2). The control is GI 6. The majority of the scions are Hedelfingen. However, because a decision was made to delay the planting of the Prosser plot until 2002, some of the rootstock selections planted in 2001 have Bing scions. The pollinator is Ulster/GI6.

There are currently 19 MSU rootstock selections, totaling 102 trees, planted at the test plot in Prosser (Fig. 3 & 4). The control rootstock is GI 6 and the scion is Bing with Tieton/GI6 as the pollinator.

At Meadow Lake Nursery, there are 32 Bing/MSU rootstock and 60 Hedelfingen/MSU rootstock selections available for spring planting in the WSU and MSU plots, respectively.

Since 2001 was the last propagation year, propagation of some of the selections from previous years was repeated in an attempt to move forward with complete rootstock sets at both MSU and WSU. Assuming 50% bud take from August 2002 budding, we anticipate that the final planting in 2004 will bring the number of MSU test selections at MSU and WSU to 93 and 70, respectively (Fig. 1 & 3). The projected final tree numbers will be 677 and 519 for MSU and Prosser, respectively (Fig. 2 & 4).

Fig. 1. The cumulative number of MSU rootstock selections currently planted and projected to be planted at Clarksville, MI. The majority of the rootstock selections have Hedelfingen scions while some of the selections also have Bing scions.

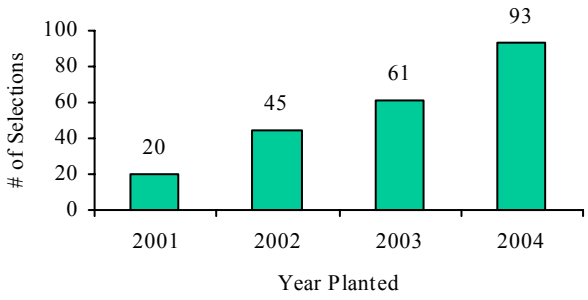


Fig. 2. The cumulative number of trees currently planted and projected to be planted in the MSU rootstock selection test block at Clarksville, MI.

Fig. 3. The cumulative number of MSU rootstock selections currently planted and projected to be planted in Prosser, WA. All of the rootstock selections have Bing scions.

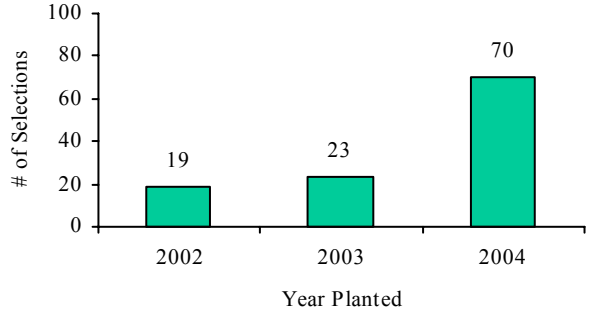
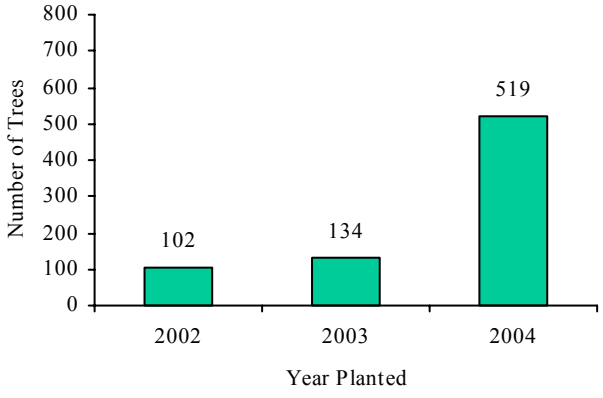


Fig. 4. The cumulative number of trees currently planted and projected to be planted in the MSU rootstock selection test block at Prosser, WA.



In Spring 2002, all the MSU rootstock selections except one induced flowering on Hedelfingen and Bing in the CHES plot that was planted in spring 2001 (Fig. 5). GI 6 resulted in a mean of 49 flowers per tree. The majority of the MSU rootstock selections resulted in a mean of 7 to 50 flowers per tree. Therefore, it appears as if selection for precocious flowering may be relatively easy. Unfortunately freeze damage to the flowers during bloom resulted in no fruit set. Based on this data, we anticipate that there will be flowering data and possibly fruiting data from the vast majority of the selections planted at the Prosser and CHES plots in 2003.

Mean cross-sectional area measurements of the MSU test rootstock selections planted in Spring 2002 ranged from 20 – 35 mm (Fig. 6). GI 6 was in the group with the smallest measurement.

Fig. 5. Mean flower numbers for GI6* and 20 MSU rootstock selections that were planted at Clarksville, MI in Spring 2001. The mean values are summed over both Hedelfingen and Bing scions.

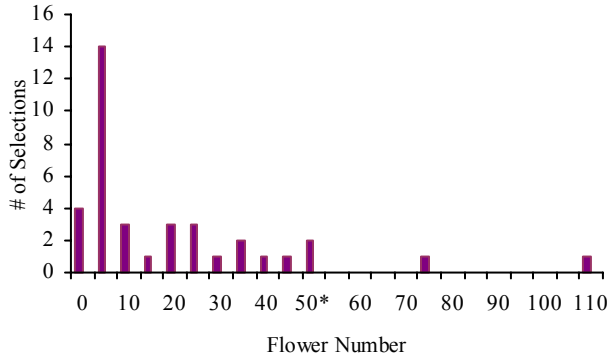
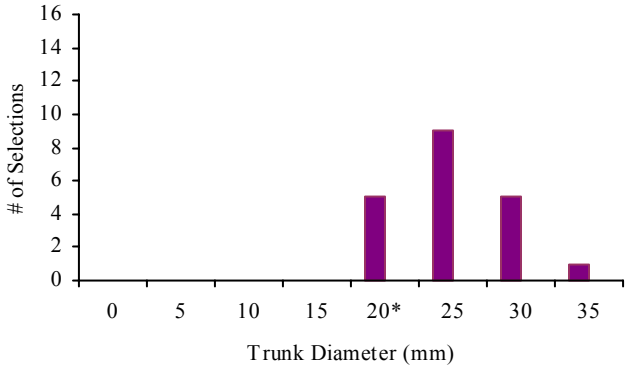


Fig. 6. Mean truck cross sectional area for GI6* and 20 MSU rootstock selections that were planted at Clarksville, MI in Spring 2001. The mean values are summed over both Hedelfingen and Bing scions.



Summary: The MSU cherry rootstock selection project is on target to complete planting of the first grafted trials at MSU and WSU by spring 2004. The abundance of bloom induced by the MSU rootstock selections planted a year ago in the MSU test plot indicate that precocious flowering is easy to achieve. This will allows us to begin to access productivity and fruit size at a young tree age.

Budget

Title: Identification of sweet cherry dwarfing rootstock candidates from MSU's tart cherry germplasm collection.

P.I.: Amy Iezzoni

Project duration: Propagation Phase (1997-2001), Transition Phase (2002-2004), Field Testing will be the only activity beginning in YR 2005.

Current year: 2003

Project total (3 years): $26,209 plus tree costs in Year 3

Current year request: $9,962

Year	Year 1 (2002)	**Year 2 (2003)**	Year 3 (2004)
Total	$10,600	**$9,962**	$5,647 *

* This number will increase depending on tree costs.

Budget breakdown:

ITEM	Year 1 (2002)	**Year 2 (2003)**	Year 3 (2004)
Salaries[1]	$2,015	**$4,010**	$2,222
Benefits [2]	621	**1,280**	725
Labor [3]	1,000	**800**	500
Supplies [4]	200	**400**	200
Fee for virus screen	3,000 [5]	**-**	-
Travel	3,000 [6]	**2,500[6]**	2,000[6]
Tree and freight costs	764[7]	**972[8]**	NA[9]
Plot costs at MSU	0	**0**	0
Plot costs at WSU	0	**0**	0
TOTAL	$10,600	**$9,962**	$5,647[9]

[1] This represents partial funding for technical support to oversee the budding at Hilltop, develop spreadsheets describing each rootstock selection and the status of all the grafted trees, collect data, and manage, analyze, and summarize the data from the 2 field plots.

[2] Benefits for YRs 2002, 2003 and 2004 are calculated at 30.8%, 31.9%, and 32.6 %, respectively.

[3] Student labor will assist with planting, data collection and management.

[4] Supplies to include tags, mouse guards, other field supplies, computer diskettes etc, and poster supplies.

[5] Fee from NRSP5 for virus screening 50 selections for PDV + PNRSV @$60 each.

[6] Travel to WSU and MLN for field map development, tree labeling and data collection. Besides the obvious benefit of looking at the trees ourselves we are familiar with all the rootstock nomenclature and can more easily verify the accuracy of the labeling, and data collection. In years 2002-3 include travel to Hilltop Nursery.

[7] 94 trees for Spring 2002 planting were purchased from MLN @$6/tree. Freight fees were underestimated.

[8] 92 trees for Spring 2003 planted will be purchase from MLN @$6/tree plus shipping. Pollinator trees for the CHES and Prosser plots will be donated from Hilltop Nurseries and Willow Drive Nursery, respectively.

[9] Not available (NA): Tree cost for 2004 will depend upon final tree number and whether the trees are donated or require payment. Therefore these budget requests will increase if there are any tree costs.

Other support: MSU support at CHES for the Iezzoni program is estimated to be ~ $40,000. Funding totaling $2,000 was obtained from the IDFTA for Year 2002 for the project entitled "First grafted trial of MSU's sweet cherry rootstock selections". However, $3,000 was requested. The intent was to use the funds to supplement that supplied by the WTFRC and OSCC. However, since

full IDFTA funding appears unlikely the budget above was increased by $3,000 from last year's projection to make sure that all project expenses are covered.

Appendix 1: Methods and Objectives for the Transition Years (2003 – 2004):

YR 2003: Plant trees generated from the YR 2000 rootstock candidates in the MSU and WSU Rootstock Test Plots, verify labeling of trees for YR 2004 planting, and collect data from the grafted trees.

Table 3: Year 2003 activities.

	Spring	Summer	Fall
MSU	▪ Purchase pollinator trees[1]. ▪ Plant pollinator trees and trees from the YR 2000 cuttings. ▪ Minimal tree training and pruning. ▪ Take trunk-cross sectional area and bloom data from rootstock plot. ▪ Plant YR 2001 cuttings in mother block.	▪ Re-evaluate plot maps and record any dead/sick trees. ▪ Investigate any selections that may be miss-labeled either by morphological or DNA differences. ▪ Evaluate crop load and fruit size from any fruiting trees.	▪ Data analysis and updating of planting/plot inventory
WSU	Purchase pollinator trees[1]. ▪ Plant pollinator trees and trees from the YR 2000 cuttings. ▪ Minimal tree training. ▪ Take trunk-cross sectional area and bloom data ▪ Travel to Prosser to assist with data collection.	• Re-evaluate plot maps and record and dead/sick trees. • Evaluate crop load and fruit size from any fruiting trees.	▪ Travel to the West Coast to attend the Cherry Research Review.
Hilltop		▪ Re-label budded trees in the nursery row that were from YR 2001 propagation.	
MLN		▪ Travel to MLN to re-label budded trees in the nursery row that were from YR 2001 propagation.	

[1] The rootstock candidates for MSU and WSU will be budded with Hedelfingen and Bing, respectively. Therefore, for each test plot, pollinator trees (WSU-Tieton/GI 6; MSU-Ulster/GI6) need to be purchased so that the Bing/Hedelfingen : pollinator ratio is 8:1.

[2] *Funds are requested to travel to Prosser to assisting in planting, map generation and data collection, MLN to tag and verify the status of the budded trees, and attend the Cherry Research Review.*

[3] Data collected: trunk cross-sectional area, bloom date, bloom density, crop load, & fruit size as the trees mature.

YR 2004: Complete the planting phase of the rootstock project at MSU and WSU & continue with data collection.

Table 4: Year 2004 activities to be accomplished by Amy Iezzoni and/or Audrey Sebolt (MSU cherry breeding technician).

	Spring	Summer	Fall
MSU	▪ Purchase pollinator trees[1]. ▪ Plant pollinator trees and trees from the YR 2001 cuttings. ▪ Minimal tree training and pruning. ▪ Take bloom and x-sectional area data[2].	▪ Re-evaluate plot maps and record any dead/sick trees. ▪ Evaluate crop load and fruit data[2].	▪ Data analysis and updating of planting/plot inventory.
WSU	▪ Purchase pollinator trees. ▪ Plant pollinator trees and trees from the YR 2001 cuttings. ▪ Minimal tree training and pruning. ▪ Travel to Prosser to assist in the data collection [bloom and x-sectional area data.][2,3]	Re-evaluate plot maps and record any dead/sick trees. Evaluate crop load and fruit data[2].	▪ Travel to the West Coast to attend the Cherry Research Review.

[1] The rootstock candidates for MSU and WSU will be budded with Hedelfingen and Bing, respectively. Therefore, for each test plot, pollinator trees (MSU-Ulster/GI 6; WSU-Tieton/GI6) need to be purchased so that the Bing/Hedelfingen : pollinator ratio is 8:1.
[2] Data collected: trunk cross-sectional area, bloom date, bloom density, crop load, fruit size. Crop load and in special cases actual yield data plus fruit size will only be collected from the most promising selections.
[3] Funds are requested to travel to Prosser to assist in tree evaluation.

YR 2005: Evaluate the MSU rootstock candidates planted in field plots at MSU and WSU for their ability to induce dwarfing and precocity. Record tree survival, cross-sectional area, bloom and fruit ripening date, fruit size, and estimates of bloom density and crop load. Crop load and in special cases actual yield data plus fruit size will be only collected from the GI 6 control and the most promising selections. Rationale: There is no need to collect data from selections that are not performing well and will obviously be discarded.

Propagation for advanced trials of promising selections will be initiated if and when any of the MSU rootstock selections look promising.